QUEENSLAND

BUREAU OF SUGAR EXPERIMENT STATIONS

DIVISION OF PATHOLOGY
BULLETIN No. 2.

A Key for the Field Identification of Sugar Cane Diseases.

BY

ARTHUR F. BELL,
Sugar Cane Pathologist.

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Bureau of Sugar Experiment Stations,

Brisbane, 4th January, 1929.

The Under Secretary,

Department of Agriculture and Stock, Brisbane.

SIR,—I have the honour to recommend for publication as Bulletin No. 2 of the Division of Pathology, manuscript entitled "A Key for the Field Identification of Sugar-cane Diseases," by Arthur F. Bell, Sugar Cane Pathologist.

I have, &c.,

H. T. EASTERBY, Director.

ACKNOWLEDGMENTS.

The writer wishes to express his indebtedness to the Director of the Experimental Station of the H. S. P. A., the Director of the Insular Experiment Station in Porto Rico, the Director of the Philippine Bureau of Science, Mr. D. S. North (Plant Pathologist to the Colonial Sugar Refining Company of Sydney), and to Dr. H. H. Storey of the Amani Institute, for permission to use photographs and reproduce illustrations. Thanks are due to Dr. E. J. Butler, Director, Imperial Bureau of Mycology, Mr. H. Atherton Lee, Director of Research for the Philippine Sugar Association, Mr. S. F. Ashby and Mr. D. S. North for a critical reading of the accompanying Key ; and, also, the Director and members of the H. S. P. A. Experimental Station staff for assistance and advice during the preparation of the manuscript.

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A Key for the Field Identification of Sugar Cane Diseases.

By Arthur F. Bell.

INTRODUCTION.

The ideal method of plant-disease control is obviously a quarantine system which would have effected, and which will continue to effect, the total exclusion of parasites from the country in question, but human frailty being what it is, an ideal is never achieved, and so we must devise means to minimise the losses arising as a result of our shortcomings in this respect. Moreover, the agricultural industries of most countries were established long before the true nature of the cause of plant diseases was even suspected. Plant pathology as a science came into being in the latter half of the last century, and the study of sugar-cane pathology was commenced only forty years ago, by which time most of the sugar-cane countries had already been introducing and propagating foreign cane varieties (and diseases) for many years. So long as the direct cause of plant diseases was unknown it was naturally impossible for the people of that day to take adequate steps towards the prevention of the introduction of diseases. In Queensland, the absence of specially trained officers has prevented the operation of a strict quarantine against foreign diseases, and we have incurred the inevitable penalty of having most of the serious diseases present in various parts of the State. Nevertheless, this statement is by no means to be taken as an argument in favour of the removal of quarantine regulations as far as sugar cane is concerned; new and serious diseases are continually being reported in other parts of the world, and we must endeavour to exclude them. The fact that we have been lax in the past renders it all the more necessary that we should be doubly strict in the future, and any grower who attempts to evade the quarantine regulations, and surreptitiously imports foreign cane is nothing less than a traitor to himself and his fellow growers. The Bureau watches developments in other countries and introduces any cane of outstanding merit, and at the same time will take all possible precautions against the introduction of a new disease.

Next to the ideal of total exclusion, the best thing is to be able to recognise a disease immediately it makes its appearance in a new locality. Prompt measures can then be taken to control the disease before it spreads over a large area and makes control difficult and expensive, and perhaps impossible except by discontinuing the planting of what may be the best varieties of that locality. It is for the purpose of facilitating the prompt diagnosis of sugar-cane diseases that this bulletin has been written, and it is to be hoped that growers will notify the Bureau immediately they discover any suspicious symptoms.

The accompanying Key was constructed by the writer as the result of a suggestion made by Mr. H. P. Agee, the Director of the Experimental Station of the Hawaiian Sugar Planters' Association, and is based on experience gained during a recently completed four years' tour of the world. In it have been considered a number of diseases which have not assumed economic importance, but it is desirable that the farmer and the field man should have a readily available means of identifying them in order that they may gauge the importance of any disease which may appear.

Discussion of individual diseases has purposely been restricted mainly to a description of the symptoms exhibited, except in the case of the non-infectious diseases classed under the heading of the growth failure complex. In the latter, the symptoms exhibited by the plant usually lack distinctive features, and so it has been necessary to give in some detail the environmental conditions under which these diseases arise. For our present purpose we will use the term " disease " to represent any abnormal unhealthy state of the plant, irrespective of how this condition has arisen. We have included a short description of the structure of the sugar-cane plant in order to explain certain botanical terms which are used in recording the symptoms of the various diseases. Reference is also made to certain elementary chemical principles, and to anyone not familiar with these we would suggest the reading of that excellent little handbook " Chemistry of the Farm, Dairy, and Household," which was compiled some years ago by Mr. J. C. Brünnich, the Agricultural Chemist.

The consideration of the so-called physiological diseases, caused mainly by unfavourable soil conditions, presents a difficulty in that one does not know where to draw the line between Pathology and Agriculture. In this connection it has been decided to restrict the discussion of unfavourable soil conditions to those which, while having marked effects, remained obscure for many years, and which are unlikely to be corrected by the ordinary cultural and fertilising practices. It is assumed that every farmer is well acquainted with the plant's need of suitable soil and temperature, good tillage, good drainage, adequate water, and of mineral plant foods, such as lime, nitrogen, phosphoric acid, or potash. It is also assumed that the farmer recognises the need for preservation of the tilth of the soil, available iron for the production of the green chlorophyll in the leaves, the need of correcting either high acidity or high alkalinity in the soil, etc. If he does not he had best read a book on elementary agriculture as soon as possible. The time is past when a farmer can profitably continue operations as a " rule of thumb " man, waging an unimaginative fight against the caprices of nature ; it becomes more and more necessary that he keep abreast of the scientific and economic developments in his particular field, and this can only be done by means of organised reading. If the average farmer would devote one hour less to manual work, and one hour more to mental work, per day his life would undoubtedly be happier and more productive.

HOW TO USE THE KEY.

In order to use the Key it is necessary to be familiar with the details of the structure of the sugar-cane plant, and a reading of the section entitled "The Structure of the Sugar-cane Plant" will help to refresh the memory on this point. To trace the identity of a specific disease the procedure should be as follows :—

Suppose that some cane in a field appears to be diseased and that yellowish streaks are evident on leaves of some of the canes. On consulting the Key we find that the symptoms of the various diseases are divided into several groups according as to whether they are exhibited by (*a*) the cane top as a whole, (*b*) individual leaves, (*c*) the leaf sheath, (*d*) the exterior of the cane stem, (*e*) the interior of the cane stem, or (*f*) the roots. We have assumed that the cane in question is showing yellowish streaks on some of the leaves and thus must be considered under class (*b*). This class is again divided into several sections depending on whether the symptoms are streaks, spots, irregular bands, or galls, and the case under consideration will naturally fall under Section I. We then examine the streaks more closely and find that they are fairly long and well defined, more or less uniform throughout the whole length, and following the course of the vascular bundles. These characteristics immediately place the disease in subsection A, which stamps it as being one of the following six diseases :— Gumming, leaf-scald, red stripe, leaf variegation, manganese chlorosis, or downy mildew. A further examination of the individual streaks indicates that they are yellowish and dotted with small red dots in some cases ; they do not pass down on to the leaf sheath but are confined to the blade ; older streaks are somewhat diffuse, losing their regularity of outline, and the tissue in the oldest portions is dead. Upon consulting the Key we find that this tallies closely with the description of gumming, and we must then turn to page 19, which contains a full list of the symptoms, in order to confirm our diagnosis.

Any suspicious symptoms which are noted in the cane, whether they be on leaves, stalk, or roots, should be run down in a similar manner, and the diagnosis confirmed by reference to the full descriptions of the individual diseases. It must always be borne in mind that all the symptoms described are rarely visible at the one time and so a considerable amount of judgment must be exercised in arriving at a decision as to the identity of any disease. It is important to note that one should not make too great an effort to make any disease fit the symptoms set out in this bulletin—it might be a new disease.

For the convenience of any one who desires more detailed information on these diseases, particularly as to the characteristics of the causal agent and the history of the disease, we have appended a bibliography of some sixty titles. Most of these publications are available at the head office of the Bureau, where they may be consulted. The list is of necessity quite short, but extensive citations of literature are included in most of the publications, should the reader require further references. The bibliography

has purposely been restricted practically entirely to publications printed in the English language. The particular publications bearing on each disease are referred to by the numbers in parentheses at the head of each description.

THE STRUCTURE OF THE SUGAR-CANE PLANT (1, 13).

[*See* Plates III. and IV. (Fig. 4.).]

In making short descriptions of the various diseases it is impossible to avoid the use of technical terms when referring to the different organs and tissues of the plant. Since there may be many growers who are not familiar with all of these technical terms, it has been thought advisable to include an outline of the structure of the sugar-cane plant. This does not in any sense attempt a complete description, but is only intended to explain the terms which are used in the text.

Sugar cane is a member of the grass family, bearing the botanical name of *Saccharum officinarum* L., and has attained its present size and high sugar-content as a result of centuries of selection by the native races of the tropics. It may be conveniently divided into the following portions :—Root, root stock or underground stem, stem, leaves, and inflorescence. The present purpose will best be served by describing these individually in that order.

ROOT.

The roots are usually brown-coloured and much branched. They have two purposes :—(1) to anchor the plant firmly in the ground, and (2) to supply the plant with mineral plant foods and water. The root system is composed of **primary, secondary,** and **tertiary roots.** The primary roots are stout, usually white and fleshy when young, and act mainly as channels for the transportation of food and water ; they branch and give rise to secondary roots, which in turn branch and give rise to the tertiary roots. The primary roots persist, but the secondary and tertiary roots are short lived and die and decay comparatively rapidly. Towards the tips of the roots are borne numerous miscroscopic hairs, the **root hairs,** through which the mineral plant foods and water are absorbed and passed into the roots. The roots are composed of several layers of tissue, the outermost being a single layer of protective cells—the **epidermis**—from which the root hairs arise. The epidermis encloses the **cortex** which is a fleshy tissue composed of soft loosely packed cells with thin walls. Within the cortex is the **endodermis,** consisting of closely packed cells with thick walls, and within the endodermis is a hard woody cylinder, the **central cylinder** or **stele,** which contains the **vascular** or **conducting tissue.** The water and mineral plant foods are absorbed through the root hairs and pass through the cortex and endodermis into the stele, through which they are transported to the stem and leaves.

Note :—Owing to the unsuitability of English units for expressing small measurements, the dimensions of disease lesions, etc., have frequently been expressed in centimetres and millimetres.

[1 inch = 2·54 centimetres = 25·4 millimetres.]

ROOT STOCK.

The root stock or underground stem is very similar in structure to the stem, but instead of being uniform in width it tapers off to the base in the form of a cone. It is from the underground stem that the roots arise as also do the shoots which grow up and form additional canes in the stool.

STEM.

The cane stem is divided into two definite regions, the internodes which are cylindrical and enclosed in a hard rind, and the nodes which form slight ridges round the stem and are the points of attachment of the leaf sheaths. Towards the top of the cane the joints become progressively shorter and culminate in a soft undifferentiated portion, called the **growing point,** which is well protected by the youngest leaves. The colour of the rind varies greatly with the different varieties of cane. Just above each node is a narrow ring, usually lighter coloured and free from the waxy covering which characterises the main portion of the internode, and covered with a number of small circular raised areas. This is the **root band** and the slightly raised areas are dormant roots which become active and grow when the cane is planted, or may also become active as the result of some disease such as sereh, when they are known as **adventitious roots.** Within the root band, and alternately on opposite sides of the internodes, arise the buds or **eyes** from which the leaf shoots grow out when the cane set is planted : the eyes sometimes sprout on the standing cane, giving rise to **side-shoots.** The eyes are soft and tender and are often the point of entry for parasites which cannot penetrate the hard rind.

The interior of the cane stem is divided into a soft juicy portion, the **storage tissue** or **pith,** and a large number of long, hard, stringy fibres. These fibres are the **vascular bundles** or **fibro-vascular bundles** and are referred to collectively as the **vascular tissue.** Vascular bundles in the cane are composed of two main parts, one of which serves mainly to carry the plant foods and water from the roots to the leaves (the **xylem**), and the other is probably mainly concerned in the translocation of sugars, etc., from the leaves (the **phloem**). In the internodes the vascular bundles run straight and parallel, but in the nodes they run criss-cross and some of them pass out into the leaf sheaths. Seen in cross-section of the stem these vascular bundles appear as so many dots in the tissue of the cane stem.

LEAF.

The leaves are divided into an upper free portion, the **leaf blade,** and a lower portion which encases the stem, the **leaf sheath.** The healthy leaf blade is of a uniformly green colour, composed of a central stout portion, the **mid-rib,** which bears two broad, flat, thin wings which constitute the blade proper. The mid-rib is broad and thick at the base, but gradually becomes smaller and can barely be distinguished at the tip of the leaf. The margins of the leaf blade are armed with small sharp saw-like teeth and the upper and lower surfaces are covered with very small spines or hairs. Both of these characters vary very much as we pass from variety to variety. The surfaces of the leaves are also covered with large numbers of very small openings, called **stomata,** through which

the leaf gives off water and takes in carbon dioxide and oxygen from the air. From the mid-rib arise large numbers of veins which run in parallel straight lines from the mid-rib to the margin of the leaf. They run out from the mid-rib at a slight angle, and the oblique tearing which is characteristic of cane leaves is due to the tearing of the weak tissue between two of these veins. The construction of these veins or vascular bundles is similar to that of the vascular bundles in the stem : they may be traced right down the leaf, through the sheath, into the stem. The youngest leaves, which are not fully developed, are rolled in and form an upright cylinder at the top of the stem ; this is known as the **central spindle.** All the leaves together form the **cane top** which consists, on the average, of about fourteen fully developed leaves plus the spindle. The green colour of the leaves is due to the presence of a green substance called **chlorophyll,** which is contained in small oval bodies called **chloroplasts.** These chloroplasts are numerous in certain cells of the leaves, particularly in the immediate vicinity of the vascular bundles. Yellowing of the leaves is caused by a breaking down of the chlorophyll, and this is termed **chlorosis** or a **chlorotic condition** of the leaves. The colour of the leaf sheath is generally green, but it becomes discoloured as it becomes older. It fits firmly around the stem, and at the lower end is firmly attached to one of the nodes of the stem. The successive leaf sheaths and leaves arise on opposite sides of the stem, one leaf arising from each node.

INFLORESCENCE.

The inflorescence is composed of a very large number of the small flowers of the cane ; it is also known as the **tassel** and the **arrow.** The flowers are borne on a much branched spike which is pushed up from the central cylinder of the cane top and stands out well above the cane which has not arrowed.

Key to Diseases.

DISEASES AFFECTING THE CANE TOP.

I Distortion or malformation of the cane top.

1. Upper leaves stunted and with scalded margins, giving a general effect of the tops having been bitten off by an animal ; small galls, 0·5–1·0 millimetre wide × 0·2–2·0 centimetres long, are present on the under surface of the leaf blades. **FIJI DISEASE.**

2. Pronounced elongation of uppermost joints, causing diseased canes to stand out conspicuously taller than the surrounding healthy cane ; cane tops are thin and the leaves small and sparse. **DOWNY MILDEW.**

3. Uppermost portions of leaves failing to unfold from the spindle, giving a twisted and tangled top which tends to stand stiffly erect. **TANGLE TOP.**

4. Various malformations of the cane top, including tangle top and stunted leaves ; irregular yellow areas, containing brownish streaks and patches, at base of some leaves ; brownish streaks often running from such leaves down into stem. **POKKAH BOENG.**

5. Long, black, whip-like appendage produced from the apex and occasionally from lateral shoots; when young the appendage is covered with a thin white membrane which later ruptures to liberate a black dusty spore mass. — **SMUT.**

II. Comparatively rapid wilting of the cane*.

A. Wilting of whole stools or single canes.

1. Production of suckers, or side shoots, which bear fine white pencil streaks on the blades and sheaths of the leaves. — **LEAF-SCALD.**

2. Dying often beginning as dead streaks in the middle of the innermost leaves; a section at base of stem shows lemon to orange-red vascular bundles. — **DRY TOP ROT.**

3. Leaves dying from the tip back along the margins, midrib remaining green later than the leaf blades; red streaks or patches in pith in early stages and cavities produced during the later stages.

(*a*) Longitudinal section of cane stalk shows upper part dry and pithy at centre, sometimes with central cavity; below, the central portion of stalk is brown, frequently with red streaks, especially at the nodes. — **COLLAR ROT.**

(*b*) Cane stalk showing red discolouration, colour unevenly distributed; red blotches with transversely elongated white centres are characteristic pith ultimately dries to a mud colour. — **RED ROT.**

(*c*) Pith a diffuse purple or red, the colour in streaks rather than in patches; no transversely elongated white areas. — **WILT.**

B. Failure of whole stool to produce normal growth.

1. Backward and stunted growth, leaves frequently light green or yellowish in colour, reduced and often rotting root system. — **NUMBER OF ROOT ROTS AND EFFECTS OF UNFAVOURABLE SOIL CONDITIONS.**

III. Pronounced stunting of leaves, accompanied by a failure to produce any stalk.

A. Numerous small grass-like shoots—

1. Small galls, 0·5–1·0 millimetre wide × 0·2–2.0 centimetres long, on under-surface of leaves. — **FIJI DISEASE.**

2. Without galls, leaves having fan-shaped appearance .. — **SEREH.**

B. Feeble shoots with white chlorotic leaves—

1. Exudation of yellow slime from fresh-cut surface of set or stubble from which the shoot has sprung. — **GUMMING.**

2. No such exudation .. .. — **LEAF-SCALD.**

* Wilting is the ultimate concomitant of almost every disease when the host is susceptible, but here we refer to the more rapid wilts which occur as a normal phase during the course of the disease.

IV. Causing or accompanied by a rotting of the cane top*.

A. Top rot associated with leaf streaks, especially on the blades of young immature leaves—

1. Leaf streaks uniform, regular outline, at first watery green, but becoming bright red, not extending on to leaf sheath. **RED STRIPE.**

2. Leaf streaks not uniform, irregular outline, at first yellow, becoming reddish-brown; extending upwards from spots with dead, ashy-coloured centres. **EYE SPOT.**

B. Top rot associated with irregular yellowish and brown areas at base of some leaves; running through stem tissue are fine brownish streaks which may broaden at intervals to give brown ladder-like lesions. **POKKAH BOENG.**

C. Top rot occurring in roughly circular patches in the field; purple discolouration of the foliage and a shredding of certain canes in the centre of affected areas. **LIGHTNING INJURY.**

D. Top rot, usually dry and without definite external symptoms. **RED ROT, ETC.**

DISEASES HAVING LOCAL SYMPTOMS ON THE LEAVES.

I. Streaks upon the leaves.

A. Streaks long, uniform, well defined, following the course of the vascular bundles—

1. Streaks yellowish, up to $\frac{1}{4}$ inch wide, with or without reddish spots, confined to leaf blade; older streaks somewhat diffuse; areas of dead tissue, at either end or intermediately in the old streaks. **GUMMING.**

2. Streaks white to pale yellow, $\frac{1}{8}$ inch wide, extending on to leaf sheath; older streaks are wider, diffuse, and surrounded by a margin of dead "scalded" tissue. **LEAF-SCALD.**

3. Streaks 0·5–2·0 millimetres wide, at first watery green, but finally becoming bright red. **RED STRIPE.**

4. Streaks white or reddish, individual streaks vary greatly in width, often several on one leaf; frequently passing on to the sheath. Streaks when narrow often lie between the vascular bundles. **LEAF VARIEGATION.**

5. Streaks pure white to sickly green, up to $\frac{1}{8}$ inch wide, confined to blade, usually many on a single leaf; tissue of older streaks greatly attacked by fungi, becoming rusty red, and the leaf may split along these lines. **MANGANESE CHLOROSIS**

6. Streaks yellowish, upwards of $\frac{1}{4}$ inch wide, numerous, separated by narrow strips of normal green or confluent; lower surface of leaves covered with soft white down. **DOWNY MILDEW.**

* Top rot is a malodorous rotting of the tissue adjacent to the growing tip and is a general symptom of the later stages of many diseases.

B. Streaks very short and broken, uniform, fairly well defined, following course of vascular bundles—

1. Streaks colourless, very narrow and short, $\frac{1}{32}$–$\frac{1}{16}$ inch wide × $\frac{1}{16}$–$\frac{1}{2}$ inch long; present on all leaves, but particularly evident on the youngest. **STREAK DISEASE.**

C. Streaks not regular or well defined, not following the course of the vascular bundles—

1. Streaks yellowish-green, giving a mottled appearance; most evident on youngest leaves. **MOSAIC.**

II. Spots upon the leaves.

A. Spots with ashy-coloured centres of dead tissue in the later stages of development.

1. Spots roughly circular, appearing on both sides of the leaves, ashy centre with reddish-brown margin; occurring mainly on older leaves. **RING SPOT.**

2. Spots elliptic, more elongated than in ring spot, on both surfaces, first pale yellow, but later becoming red with ashy coloured centre and yellow margin; attacking younger leaves. On susceptible varieties the margin is enlarged to a long yellow streak (up to 36 inches long) which later becomes a reddish-brown colour. **EYE SPOT.**

3. Spots oval in early stages, tri-coloured, centre brown, next red, and yellowish margin; old spots have ashy-coloured centre with deep brown margin; appearing on youngest leaves, and remaining through to maturity. **BROWN SPOT.**

B. Spots do not develop ashy-coloured centres of dead tissue—

1. Spots roughly circular, when mature are a reddish-brown with a very narrow yellow border; tissue in centre of spot is not dead, as distinguished from ring spot and eye spot. **RED SPOT.**

2. Spots irregular, bright yellow, on upper surface, later showing red dots or patches; old spots are frequently a dull red. **YELLOW SPOT.**

3. Spots minute, brownish, elongated, on both sides of leaves, slightly raised on lower surface where they later become erupted and expose yellowish masses or spores. **RUST.**

III. Irregular bands on leaves.

1. Bands colourless, extending across whole or portion of the blade, up to 4 inches long, upper and lower margins very irregular; midrib and large veins frequently remain green. Usually only one band per leaf but generally two or more such bands on each affected cane. **SECTIONAL CHLOROSIS.**

2. Bands yellowish, usually with brownish patches and streaks, at base of leaves; upper part of leaf appears normal; brownish streaks may often be traced from the leaves, down the leaf sheath, and into the stem. **POKKAH BOENG.**

3. Bands irregularly coloured, first dirty green and finally yellow to white, with a purplish border; very irregularly shaped, but in general broader than long; successive bands are separated by narrow green or brown areas; usually on the lower part of leaves and occasionally on the leaf sheaths. **BANDED SCLEROTIAL DISEASE.**

IV. Galls upon the leaves.

Galls on the under surface of leaves, 0·5–1·0 millimetres wide × 0·2–2·0 centimetres long, formed by the enlargement of vascular tissue. **FIJI DISEASE.**

DISEASES HAVING SYMPTOMS ON THE LEAF SHEATH.

1. Lower leaf sheaths bound together by a white mycelium which produces a bright orange-red rot of the invaded tissues; affected areas are irregular and with indistinct margins. **RED ROT OF THE LEAF SHEATH.**

2. Leaf sheaths cemented into a hard unyielding jacket which prevents the further upward growth of the cane; the top often becomes much twisted in efforts to break free. Confined mainly to younger shoots and suckers. **ILIAU.**

3. Sheaths bearing bright red spots, first regular and sharply delimited but later enlarging into irregular and ill-defined patches with brownish centres of dead tissue; on removing successive leaf sheaths the infected area is seen to become progressively smaller. **RED SPOT OF THE LEAF SHEATH.**

DISEASES HAVING SYMPTOMS ON THE EXTERIOR OF THE CANE STEM.

1. Mottling of the stem, formation of cracks and cankers (varietal characteristics). **MOSAIC.**

2. Stems short and stunted, prolific production of adventitious roots from the aerial nodes. **SEREH OR ALUMINIUM TOXICITY.**

3. Stalks shrunken and discoloured with dark-bluish patches; rind covered with large numbers of small eruptions from which later exude small black, threadlike spore masses. **RIND DISEASE.**

4. Numerous small flat galls produced below the leaf sheaths, mainly at the nodes; very young galls drying up on exposure to the air. **STEM GALL DISEASE.**

DISEASES HAVING SYMPTOMS IN THE INTERIOR OF THE CANE STEM.

I. Pronounced and general discolouration of the stem tissue.

1. Red discolouration, colour unevenly distributed, dark red blotches with transversely elongated white centres, pith ultimately drying to a mud colour. **RED ROT.**

2. Upper portions of stem pithy, with dry tissue of cavity at centre ; in lower portions of stem the tissue is brown, with some red streaks. **COLLAR ROT.**

3. Tissue a diffuse purple or red, colour in streaks rather than in patches in all but the most advanced stages ; no transversely elongated white areas. **WILT.**

4. Central core a sooty-black mass of rotted tissue and spores, distinct odour of pineapples ; mainly confined to seed cuttings, but sometimes attacking standing cane in wet weather. **PINEAPPLE DISEASE.**

II. Restricted discolouration of the stem tissue*.

A. Pronounced reddening of the vascular tissue, particularly at the nodes—

1. Red colour frequently greatest in amount in the vicinity of growing point ; deposition of reddish gum in the xylem. **GUMMING OR LEAF-SCALD.**

2. Red colour not usually apparent at growing point but increasing in amount as it passes down the stem ; deposition of reddish gum in both phloem and xylem. **SEREH.**

B. Fine brown longitudinal streaks of variable length, usually few in number ; at intervals streaks broaden out (usually less than 0·5 cm. wide) to give lesions which consist of a series of lentiform cavities and which on sectioning have a characteristic ladder-like or chain-like appearance. **POKKAH BOENG.**

C. Lemon to orange-red discolouration of the vascular bundles of the lower and subterranean parts of the stem, due to the presence of the plasmodia and spores of the causal agent. **DRY TOP ROT.**

D. Discoloured reddish-brown areas containing small "pockets" filled with a yellow to yellowish-red bacterial slime. **GUMMING.**

III. Exudation from the cut ends of stems.

1. Exudation of a pale yellow to yellowish-red sticky bacterial slime from the vascular bundles, especially when a portion of the stem is placed in a small closed container. **GUMMING.**

IV. Presence of galls in the stem tissues.

1. Small whitish galls, 0·5–1·0 millimetre wide × 0·2–2.0 centimetres long, embedded in the tissue and consisting of enlarged vascular bundles. **FIJI DISEASE.**

* In general it is considered that the reddening of the vascular tissue is a symptom of a number of diseases, and is not necessarily specific to any group of diseases.

DISEASES HAVING SYMPTOMS IN THE ROOTS.

I. A general failure of growth, development of less than the normal quantity of roots, followed by a yellowing and wilting of the cane top and a rotting of the roots present.

A. Non-infectious diseases caused by unfavourable concentrations of inorganic salts in the soil solution—

1. High concentrations of saline material, usually confined to irrigated soils; injurious in neutral or slightly alkaline soils.	**SALT INJURY.**
2. High concentrations of soluble aluminium and ferrous iron salts, to be sought particularly in soils of pH 5·8 and greater acidity. Accumulation of Al and Fe in the stem, especially in the nodes, as shown by Hoffer's test; premature death and "firing" of older leaves, shortening of internodes, and production of adventitious roots from the aerial nodes.	**ALUMINIUM AND FERROUS IRON TOXICITY.**
3. High ratio of magnesium or sodium to calcium in the soil. Spindly growth and yellowing of the leaves may be very pronounced.	**GROWTH FAILURE DUE TO UNFAVOURABLE BASE RATIO.**

B. Infectious diseases caused by some (possibly many) of the soil-inhabiting fungi—

1. Invasion of cortex and stele by the fungus, causing roots to become red cankered, flaccid, and watery; attacking young roots under apparently normal as well as unfavourable soil conditions.	**ROOT ROTS OF PYTHIUM TYPE.**
2. Invasion of cortex of roots by weak parasites, following a period of unfavourable conditions or injuries by nematodes, centipedes, snails, etc.	**ROOT ROTS OF MARASMIUS TYPE.**

II. General failure of growth caused by destruction or mutilation of roots by soil fauna, usually followed by the entry of weak parasites and subsequent rotting of the roots.

A. Presence of nematodes*	**NEMATODE INJURIES CAUSED BY—**
1. Longitudinal lesions on new roots, originally reddish, later with purplish to black centres, finally becoming purplish to black.	**Tylenchus similis.**
2. Terminal galls on primary and secondary roots ..	**Heterodera radicicola.**
3. Swellings along spindles of primary roots, not true galls, often accompanied by the proliferation of secondary roots.	**H. radicicola or H. schachtii.**

* Swellings which very closely resemble nematode galls are often found in roots following an injury caused by contact with a stone or some foreign body in the soil.

4. Lignification of cortex which becomes irregularly coloured, but no galls, swellings, or proliferation of secondary roots. **H. schachtii.**

B. Pitting of the cortex by microscopic soil fauna such as springtails, centipedes, snails, etc.; these organisms rarely, if ever, invade the stele. In these cases the only above-ground symptom is a diminished tonnage. **MACRO-FAUNA INJURY.**

III. Stunting and death of the canes caused by flowering parasites which attack the roots and bear their flowers at the base of the stool.

1. Flowers purplish to black, pitcher shaped, borne singly on long floral stalks which are red with white stripes; leaves rudimentary and scale-like; plants may be up to two feet high. **BUNGA.**

2. Flowers small, light pink or white to light blue, sessile, borne terminally in clusters; plants usually upright, 6–9 inches high, leaves small, green, and lancet-shaped. **CANE-KILLING WEED.**

GUMMING (10, 51).

Alternative names—Gum disease, bacterial gummosis, gomosis, Cobb's disease, maladie de la gomme.

Causal agent—*Bacterium vascularum* (Cobb) Greig-Smith.

APPEARANCE OF DISEASE. (Plate I.)

Gumming disease is primarily a disease of the vascular system of sugar cane. The most convenient symptom for field diagnosis is the presence of characteristic streaks upon the leaves of diseased cane. These streaks may be up to a quarter of an inch wide, but are usually less; they vary in length from a couple of inches to almost the whole length of the leaf blade. Streaks may arise in any portion of the leaf blade, but the majority arise near the margins and towards the apex of the leaf. They follow the course of the vascular bundles and as a result are straight and fairly regular in outline and uniform in width. The colour of the streaks is a yellowish-brown to yellow, usually dotted with a large number of small red blotches. In the older leaves, at the point of origin of the streak, there arise areas of dead tissue which gradually elongate in both directions, and at the same time the older streaks become diffuse and lose some of their regularity of outline. These leaf streaks are best found after a period of wet weather: they are not found on the youngest leaves, and are confined to the leaf blades. In the case of systemic infection, however, the streaks may be traced down the leaf sheath, although they are faint and ill-defined. When cut open the stems of diseased canes show a pronounced reddening of the vascular bundles, particularly at the nodes. The exudation of a yellow-brown sticky "gum" or bacterial slime from the ends of freshly cut stalks is the outstanding characteristic of this disease and is responsible for the name of gumming disease. When the disease is severe this exudation takes place freely, and the juice

expressed from cane in this condition causes a great deal of trouble in the mill on account of the action of the gum in preventing the crystallisation of the sugar. In less-severe cases it is often necessary to place a piece of freshly cut cane in a closed container (*i.e.*, in a closed tin can or in the top of a hat, which is then replaced on the head) before the gum will flow. A longitudinal section of a badly diseased cane will frequently show "gum pockets," *i.e.*, small cavities in the tissue filled with the gum. The abnormal production of side shoots from the eyes of the cane is also commonly associated with this disease. All symptoms are, unfortunately, capable of being masked for long periods of time, even in the most susceptible varieties; the leaf symptoms are often absent, particularly in dry weather.

GENERAL REMARKS.

This disease is highly infectious and is readily transmitted by means of cane knives and agricultural implements. Spread from plant to plant may also take place in moist weather, when the organism passes from leaf to leaf through abrasions in the epidermis; this is probably the most important mode of spread within a field. Certain insects can act as carriers, particularly in the transmission from field to field, but it is considered that they merely carry the organism mechanically on their body parts. Losses are very heavy, both in the mill and in the field, where susceptible varieties are killed outright in dry weather. The only methods of control are through the use of resistant varieties and the selection of healthy seed, in addition to the sterilisation of cane knives, etc. In carrying out seed selection it must be borne in mind that if the leaf symptoms are found in only a single stool then all cane within a radius of a quarter of a mile is unsafe for seed. As far as possible seed beds should be established in isolated positions, and every precaution taken to prevent the disease from getting into the cane. Such seed beds should be inspected very frequently. If the area of infection is believed to be small and isolated, the cane should be immediately ploughed in; the organism does not live and multiply in the soil and no case of infection through the soil is known.

Gumming is reported from Australia, Mauritius, Porto Rico, St. Kitts (British West Indies), Brazil, and Colombia.

LEAF-SCALD (50).

Alternative name—Java gumming, gomziekte.

Causal agent—*Bacterium* sp.

APPEARANCE OF DISEASE. (Plates II. and VIII.)

Leaf-scald resembles gumming in being primarily a disease of the vascular tissues; the two diseases have many points in common and until recently considerable confusion existed as to their separate identity, or not, but that they are two distinct diseases has been demonstrated by

the publications of North, in Australia, and Wilbrink, in Java. Two distinct phases of leaf-scald occur and they have been classed as (*a*) chronic, and (*b*) acute.

Chronic Phase.

The main external symptom from which a diagnosis may be made is the presence of narrow white streaks upon the leaves of the diseased plants. The streaks are quite straight and regular, and follow the course of the vascular bundles, as in the case of gumming, but the streaks are white, or only a very pale yellow, and are more sharply defined. Moreover, they are not restricted to the leaf blade but may pass down on to the sheath; after passing on to the sheath they frequently assume a purplish colour. The width of the streaks varies from about one-eighth of an inch to a fine barely visible line; they may traverse the whole length of the leaf blade and sheath or they may be very short; they may be observed on the youngest leaves. Older streaks become broader and lose their sharpness of outline, develop irregular reddish areas along the streak, and later become withered, the withering usually starting from the margin of the leaf and proceeding inwards. This imparts to the leaf the "scalded" appearance from which the name of the disease is derived. Frequently the withering of the leaf tissues does not take place in damp weather but it is rapid in dry weather, causing the obliteration of the streaks on the leaf blades. Another characteristic is the profuse production of side shoots by diseased canes; these side shoots also bear the typical streaks on the blades and sheaths of the leaves, and are of great value in diagnosis, particularly when the leaves of the main stem are withered. Reddened vascular bundles are common, especially at the nodes.

Acute Phase.

Plants afflicted with the acute form suddenly wilt and die, the general appearance being that of a plant suddenly cut off from its root system. The wilting may involve the whole stool or only certain stalks of the stool. In the acute form it is often difficult to make a positive diagnosis and to do this it is necessary to search the base of affected stools for the side shoots and suckers which bear the very narrow white stripes upon the blades and sheaths of the leaves.

GENERAL REMARKS.

The disease may be transmitted by means of infected seed, infected cane knives, and by other unknown means in which insects are believed to play a part. The methods recommended for the control and eradication are the same as those recommended in the case of gumming, but it is found that the varietal susceptibility to the two diseases is quite different.

Leaf-scald is reported as being present in Fiji, Australia, Formosa, the Philippines, and Java.

RED STRIPE (29, 30).

Causal agent—*Phytomonas rubrilineans* Lee et al.

APPEARANCE OF DISEASE. (Plate IX.)

The main diagnostic symptom is the presence of long narrow red streaks running longitudinally along the leaves. These streaks range 0·5–2·0 millimetres in width and remain fairly uniform throughout their whole length ; sometimes two or more will run together to give a fairly broad band. The streaks vary greatly in length but usually arise midway between the tip and the base of the leaf ; the first streaks tend to arise near the midrib while the later ones arise further out from the midrib but not at the extreme edges of the leaf. Streaks are frequently found on the lower side of the midrib but rarely on the upper ; they do not pass on to the leaf sheath except in very badly affected canes. The colour of the streaks is originally a dark watery green but they gradually change to a bright red. Infection is heaviest on the middle-aged leaves and less on the older leaves ; in severe cases the immature leaves in the spindle are affected, and this is usually followed by a top rot and the production of side shoots. The effects of the disease are much more marked on young cane than on old and are most pronounced on young ratoons. The young shoots in ratoons frequently show a top rot when 1–2 feet high and die back as a consequence. The disease is confined mainly to the cane top and leaves and does not pass down into the stalk as a rule. Red stripe appears to be very closely related to, or identical with, the red streak or top rot of Queensland, with the distinction that Badila is quite susceptible to red streak in Queenaland, but is reported as being resistant to red stripe in Hawaii. The disease known as " polvillo " in Brazil and the Argentine also appears to have features in common with these two diseases.

GENERAL REMARKS.

The disease is transmitted from leaf to leaf during moist weather, presumably through lesions made by the spines which exist along the margins of the leaves. Insects may also play a part in the transmission but experiments show that the use of seed from diseased fields is not of much importance in the spread of the disease. In Hawaii red stripe is confined mainly to the " Tip " canes—Yellow Tip, Striped Tip, and Red Tip—and so far has not been found on any of the related grasses. For the purposes of control it is inadvisable that cuttings should be transferred from localities in which the disease is known. Since the disease is primarily a disease of the young cane, and requires wet weather in order to spread from one plant to the other, agricultural practice should be such as to get the cane to a height of 3 feet, or more, before the rains set in. Resistant varieties should be grown in those localities in which the weather conditions favour the disease.

Red stripe is reported as being present in Hawaii, Louisiana, Cuba, and probably in Java.

MOSAIC (3, 15, 25).

Alternative names—Yellow stripe, mottling disease, matizado.

Causal agent—A so-called filterable virus.

APPEARANCE OF DISEASE.

Mosaic is now so thoroughly widespread throughout the world that a description of its symptoms is probably superfluous. Indeed, with the exception of Mauritius, and some of the smaller islands of the British West Indies, mosaic is probably to be found anywhere where cane is grown commercially. The one characteristic feature which is used for diagnosis is the presence of a curious "mottled" pattern upon the leaves, caused by the contrast of light-green areas against the normal dark green of the leaf. The light-coloured areas are irregular in size and shape and have indistinct margins; the long axis of the markings is in the general direction of the long axis of the leaf, thus causing the leaf to bear a somewhat striped appearance. The light-green colour of these areas is due to the partial suppression of the development of the chlorophyll. The pattern is quite distinct on the younger leaves, and positive diagnosis is made on an examination of these as the markings become indistinct on the older leaves. The symptoms vary somewhat according to variety. In addition to the leaf markings there are also secondary symptoms such as the mottling of the rind and the formation of cankers in the stem; as a rule, however, these are only produced in advanced stages of the disease in susceptible varieties.

GENERAL REMARKS.

The mosaic of cane is transmitted from diseased to healthy plants by the corn aphid, *Aphis maidis*, but it is quite possible that other insects are also concerned in the spread of the disease, although this has not been demonstrated up to the present time. The disease is readily transmissible to several species of wild and cultivated grasses which exhibit more or less typical symptoms and which can usually be found after a short search around the headlands and drains of cane fields. In addition these grasses harbour the insects which transmit the disease. Complete control can be effected through the use of resistant varieties, careful selection of clean seed, roguing out of diseased stools, and the eradication of grass and weeds from the fields. In fact, it is probably quite safe to grow susceptible varieties of cane if the other precautions are strictly adhered to.

STREAK DISEASE (57).

Causal agent—A so-called filterable virus.

APPEARANCE OF DISEASE. (Plates IV. (Figs. 2 and 3) and V.)

Leaves of a sugar-cane plant affected with this disease present a characteristic pattern formed by colourless narrow broken stripes which follow the course of the vascular bundles. Individual stripes are one-quarter to one-half millimetre wide, uniform in outline, and vary from

one-half a millimetre to over one centimetre in length ; occasionally two or more stripes may run together to give comparatively long stripes. The distribution of the markings on any single leaf-blade is uniform. Positive diagnosis is only made after finding these markings upon the youngest leaves, on which the pattern stands out very clearly. By transmitted light the light areas in the leaf of a plant affected with mosaic are seen to be pale green, or yellowish, while those in the case of streak disease are quite colourless. The two diseases may readily be distinguished when occurring on the same plant.

GENERAL REMARKS.

Streak disease was recently (1925) reported and described from South Africa. This disease is of great importance in that it readily attacks the Uba cane, which is considered to be immune (or practically so) to mosaic. In addition to Uba, Badila, H.Q. 694, Black Innes, and Cavangerie are considered to be susceptible varieties. The disease is spread from diseased to healthy plants by means of the leaf hopper *Balclutha mbila*. In addition to sugar cane the disease also attacks maize, teosinte, millet, oats, and a number of wild grasses ; it may be transmitted from any one of these to sugar cane. It is estimated to cause a loss of 12–50 per cent. in Uba, which constitutes almost the entire crop of South Africa. The measures for the control and eradication of the disease are the same as those recommended for mosaic.

Streak disease is reported as being present in South Africa, Mauritius, India, and Egypt.

FIJI DISEASE (14, 36).

Causal agent—Undetermined, possibly of the filterable virus type.

APPEARANCE OF DISEASE. (Plates VI. and VII.)

Though difficult to describe adequately, canes affected with Fiji disease are extremely easy to detect when once the observer has become familiar with their appearance. Diseased seed will always give rise to diseased plants, but in cases of secondary infection the symptoms may be masked for very considerable periods of time. In the field the outstanding symptom is a dwarfing and curling-in of the youngest leaves, the margins of which often present a slightly scalded appearance. Although the length of the leaves is greatly reduced, the width remains normal and the apex of the leaf, instead of being pointed, is blunt. The whole effect is as though a mule or some such animal had bitten off the tops of the leaves. As the disease progresses all the leaves in the cane top display these symptoms and become slightly darker than normal. A positive diagnosis can only be made after finding the characteristic galls which are the only symptom strictly peculiar to Fiji disease. These galls occur on the lower surface of the leaves, being about 1 millimetre in diameter and usually a few millimetres in length ; sometimes they are much enlarged and confluent, in which case they may be several inches long. They follow

the course of the vascular bundles and are, in fact, caused by the enlargement of the vascular tissues; they are readily found on the short abnormal leaves, and to a lesser degree on the apparantly normal leaves. After a close inspection, galls may usually be found before any stunting of the leaves is noticeable. Galls formed by the enlargement of the vascular tissue may also be found within the tissue of the cane stalk, particularly in the region of the growing point. No further elongation of the stalk takes place after the production of the distorted leaves described above, and the stunting of the canes quickly becomes evident. Frequently, when badly diseased seed is used, there is no production of an aerial stalk and the plant is reduced to a crown of very small leaves which are approximately the size of the leaves which are produced on side shoots. This appearance is more characteristic of ratoons than of plant cane.

GENERAL REMARKS.

No artificial transmission of the disease has yet been carried out, and no organism has been proven to be associated with the disease. It is considered that the causal agent probably belongs to the group known as the filterable viruses and an insect vector is suspected as being responsible for transmission in the field. Control is practised mainly through resistant varieties and the selection of healthy seed; for the latter purpose it has been found that the seed should be selected from medium to poor land, a clayey soil being preferred. Any diseased stools found after planting should be immediately rogued out and destroyed.

Fiji disease is reported as being present in Fiji, Australia, Philippines, and has been observed in New Guinea.

SEREH (36, 58, 59).

Causal agent—Unknown.

APPEARANCE OF DISEASE. (Plates X. and XI., Fig. 13.)

The definite diagnosis of sereh is very difficult, and there have been false reports of its presence from several parts of the sugar world. The exact symptoms exhibited by a sugar-cane plant affected with sereh vary greatly according to the variety of the cane and the degree of severity of the disease, but the general effect is to cause premature death or arrest the growth of the cane so as to give short stunted useless stalks. In severe cases, in some varieties, no appreciable stalk is formed and the leaves consequently arise very close together, their appearance resembling that of the leaf of a fan palm, and in this stage the stool resembles a tuft of lemon grass (*Andropogon schœnanthus*) for which the native Javanese name is "sereh," and hence the name of the disease. On the other hand some varieties maintain internodes of the normal length, but the disease causes the very early death of the cane. The most common symptom is a pronounced red discolouration of the vascular tissue owing to the presence of a red gummy substance in both the phloem and the xylem; when present this is one of the later stages of the disease. Individual

vascular bundles may be discoloured for a distance of 2–3 internodes or for only a very short distance. The reddening is most pronounced in the cross bundles at the nodes and it is here that the incipient reddening must be sought. The discolouration may sometimes be found in the vascular bundles of the leaves, in some varieties the main veins of the leaves appear as thin red streaks, particularly when the leaf is held up to the light. Another common feature is the prolific production or comparatively long and much-branched roots from the aerial nodes of the stem.

Which of the symptoms are present, and which predominate, is determined by the variety and the stage of the disease. Several of these symptoms may be shown by cane which is growing under unfavourable environmental conditions; for example the production of aerial roots is a characteristic of cane growing in acid soils which contain toxic amounts of soluble aluminium salts. The disposition of the reddened bundles may be of great value in distinguishing sereh from such diseases as gumming and leaf-scald. In sereh the invariable rule appears to be that the reddening is first visible some distance below the growing point and increases in amount as it passes downwards. With gumming, and to a somewhat lesser extent with leaf-scald, the rule is that the red colour is most pronounced in immediate vicinity of the growing point and decreases in intensity as it passes downward. When growing conditions are favourable, canes affected with gumming or leaf-scald may "grow away" from the disease, in which case the discoloured areas will be found at some distance below the growing point. The disease is cumulative in its effects, *i.e.*, a set from a slightly diseased cane will give rise to a plant in which the disease is more pronounced, and so on.

GENERAL REMARKS.

The cause of sereh is quite unknown and there is not even any proof that it is an infectious disease; it has characteristics common to virus, bacterial, and physiological diseases, and each of these theories has its supporters. Once considered the dreadful scourge of the sugar industry in Java, this disease is now regarded in the light of a blessing in disguise as it was responsible for the introduction of scientific control of sugar-cane production and the establishing of the experimental stations. Complete control was soon obtained through the use of resistant varieties, the elimination of ratooning, and the careful selection of healthy seed. For this latter purpose advantage is taken of the fact that the natural spread of the disease is apparently restricted to the lowlands. Hence, starting at an elevation of some 5,000 feet and descending, there are successively "grandmother" fields, "mother" fields, and propagation fields, the latter being in the lowlands. Bibits (seed pieces) were taken from the grandmother fields to plant the mother fields, whence the bibits were taken to plant the propagation fields and from here the healthy seed was sent out to the lowland plantation fields. At the beginning of the present decade the hot-water treatment of bibits was introduced and proved to be a practical means for controlling sereh and eliminating the necessity for

upland nurseries. This hot-water treatment consists in steeping the bibits in water at 52°C. for 30 minutes and then drying for one day before planting. However, with the planting of almost 100 per cent. of the highly resistant P. O. J. seedlings, measures for the control of sereh have ceased to be necessary, and at present the disease has only an historical interest.

At the present time sereh appears to be confined to Java and perhaps Formosa.

POKKAH BOENG (2, 58).

Causal agent : *Fusarium moniliforme.*

DISCUSSION OF IDENTITY.

Pokkah boeng is a Javanese expression which means "damaged top." As used by the natives it is a quite-general term and includes all types of malformation and damage to the cane top ; Fiji disease, for instance, would doubtless be designated pokkah boeng were it to appear in Java. More than thirty years ago Wakker and Went described a disease under the name of pokkah boeng ; this was characterised by a distortion of the cane top, often accompanied by a top rot. Wakker found bacteria associated but could not reproduce the disease with the bacteria isolated. After considering the available evidence Wakker and Went came to the conclusion that the disease was caused mechanically by the constriction of the young rapidly growing tissues at the beginning of the rainy season. Owing to the unimportance of the disease no further work was done until 1926 and the mechanical hypothesis was tacitly accepted during that period. In 1926 a new investigation of the disease was undertaken on account of the fact that it had suddenly become important as the major disease of the new seeding P.O.J. 2878. The result of these investigations was to demonstrate the infectious nature of pokkah boeng, and the causal agent was shown to be *Fusarium moniliforme*. From a consideration of the symptoms of pokkah boeng as described by Wakker and Went, and the evidence of people long associated with the sugar industry in Java, there is no doubt as to the identity of the disease in the two periods of time. In Java the term pokkah boeng is now being restricted to this particular disease, although a more specific name is perhaps desirable.

In most parts of the sugar world one can frequently see canes with tangled and distorted tops, and this type of injury is often called pokkah boeng. While there is no doubt that such abnormal conditions are literally cases of pokkah boeng (since they have "damaged tops") nevertheless considerations of priority, and the necessity for avoiding confusion, rule that the name of pokkah boeng must be restricted to the distortion and top rot caused by *Fusarium moniliforme.*

APPEARANCE OF DISEASE. (Plate XII.)

In the field the general appearance of the diseased canes varies a great deal according to the severity of the disease. In cases of light infection there is no obvious distortion of the cane top as a whole, but when distortion

is present it may range from a stunting of the leaves to a complete matting and tangling of the entire top ; in the ultimate stages of heavy infection the tops are dead and rotted. The first symptoms are seen in the presence of irregularly shaped, yellow chlorotic areas at the base of the young leaves, the upper part of the leaves appearing quite normal. The symptoms may be confined to a single leaf or may be present on a series of leaves ; the yellowed area may extend right across the leaf blade or may lie only on one side of the mid-rib. Reddish-brown streaks and patches of dead tissue soon appear and they may remain of small size or may gradually extend over the greater part of the yellow portion of the leaf. As a result of this great weakening of the tissue the leaves frequently break at this point and hang limply down the stalk. In many cases, particularly later in the season, the zone of infection may not extend beyond the leaf but otherwise it may be traced, in the form of fine brownish streaks, down the leaf sheaths and into the stem. These streaks may be very short or they may pass down the stalk for a distance of several internodes ; at intervals they may broaden out and give well-defined brownish longitudinal lesions which may be up to several centimetres long, but the majority are less than half a centimetre in diameter. They consist of a series of cavities so that on sectioning they present a very characteristic ladder-like or chain-like appearance which serves as the most important diagnostic symptom of the disease. Since the diameter of the streaks and ladder-like lesions usually is so small it is important that suspected canes should be sliced very thinly, otherwise the symptoms may be missed. There may be from one to several such streaks in the one internode. If the line of infection from the leaf sheath does not penetrate very far into the stalk, the typical ladder-like lesions may be formed on the surface of the rind. The presence of a surface lesion restricts the growth on that side of the internode and causes the stem to be bent and twisted. In badly diseased canes the lesions enlarge so as to involve all or most of the tissues adjacent to the growing point, giving rise to a top rot which causes the death of the cane. A microscopic examination will show that the brownish streaks are caused by the more or less complete destruction of the cells of the vascular bundles which are filled with a reddish-brown gummy mass. The hyphæ of the causal fungus can readily be found in the vascular bundles and the immediately adjacent cells.

GENERAL REMARKS.

Infection takes place in the young immature leaves of the spindle, and penetration of the stem tissues is effected while the internodes are very young. The damage done by the disease is greatest in the early part of the rainy season, *i.e.*, when the cane is young and growing rapidly ; at this time the top-rot stage of the disease is most prevalent and in some localities is responsible for a considerable loss of cane. The disease is confined mainly to the varieties P.O.J. 2878 and P.O.J. 2722. So far all attempts to transmit the disease through the planting of diseased seed have been without result, but as yet there is no known method for the control of the disease.

Pokkah boeng is definitely reported from Java, but now that the etiology of the disease is established it is likely that it will be found in other countries.

SMUT (4, 52).

Causal agent—*Ustilago scitaminea* (Rab.) Syd. (*Ustilago sacchari* Rabenh.).

APPEARANCE OF THE DISEASE. (Plate XIII.)

This disease is extremely easy to recognise owing to its one outstanding characteristic, viz., the production of a long black sooty, whip-like, appendage which arises from the growing apex. This shoot probably represents an inflorescence which has been stimulated to abnormal growth and activity by the attack of the causal fungus. It may be up to several feet long and is usually much curved back upon itself. In the early stages this appendage is covered with a thin white membrane, the raised epidermis, which later ruptures and exposes the black dusty spore mass. In cases of general infection throughout the plant the side shoots from the eyes on the lower portions of the plant also produce this type of appendage. As a rule the affected plants do not exhibit symptoms of smut infection until nearing maturity. In India practically all the canes which are susceptible to smut belong to the group of thin canes.

GENERAL REMARKS.

Infection takes place in the seed piece and through the tender buds of the growing plant, the latter probably being the more usual method. No specific measures of control have been developed owing to the restricted incidence of the disease. As a general precaution a practice should be made of burning diseased canes as soon as they are observed and also avoid growing the susceptible thin varieties when the disease has once made its appearance.

Smut is reported as being present in Formosa, Philippines, Java, India, and Mauritius.

TANGLE TOP (32).

Alternative names—Twisted top, top knot.

Causal agency—Mechanical.

APPEARANCE OF DISEASE. (Plate XIV., Fig. 18.)

In most cane fields there appear at times canes which have malformed or distorted tops, due to the entanglement of the leaves one within the other. Such a condition has frequently been termed "pokkah boeng," but it is considered that the application of this term leads to confusion and should be discontinued; a discussion of the separate identity of tangle top and the pokkah boeng of Java will be found on page 27. Tangle top probably occurs most frequently in Hawaii, particularly in the seedling H. 109, and has been fully investigated during the past year. Here one frequently sees cane tops standing conspicuously erect and rigid, due to the fact that the leaves are not expanded in the normal manner but are split and torn and wrapped ribbon-like around the central spindle. The

effect of this is to prevent the younger leaves from emerging freely from the spindle, and to cause the cane top to become stunted and mis-shapen. Sometimes the cane will "grow out" of this trouble but at other times the plant "strangles" itself, causing a cessation of growth which may be followed by the death of the growing point. The inner leaves are found to be of a lighter colour than normal, much corrugated, and often very much twisted. Less-advanced stages may be seen when the leaves are not torn and only the tips are bound together, the bases being expanded normally. The disease is more common around the edges than in the middle of the fields and more common in the actively growing shoots and suckers.

GENERAL REMARKS.

The recent work of Atherton Lee has shown clearly that the tangle top of Hawaii can be reproduced at will, merely by increasing the mechanical friction between the leaves as they emerge from the spindle. The methods used were (1) tightly binding the central spindle at the top with adhesive tape about an inch wide, and (2) bending the central spindle abruptly at a point about half way up the spindle. In practically every case the typical twisted top followed such treatment. The writer has also observed tangle top to follow a distortion of the young leaves brought about by fertiliser burn.

The evidence, therefore, shows that the tangle top of Hawaii is the result of mechanical friction between the young leaves. The surfaces of the cane leaves are covered with innumerable small spines and, considering the fact that the leaves within the spindle are growing at very different rates, it is easy to imagine that the friction would sometimes be sufficient to cause a twisting and buckling of the immature leaves. This in turn would hinder the development of the still younger leaves, causing them to become distorted, and the effect of tangle top would be produced. Tangle top is common in the varieties H. 109 and H. 456, both of which have a marked development of surface hairs or spines: on the other hand such varieties as Yellow Caledonia and Badila have a restricted development of leaf hairs and rarely show tangle top. The disease is common in the more arid situations, where there is a greater development of leaf hairs and little rain or dew to act as lubricants in the leaf spindle. Since merely bending the leaf spindle is sufficient to induce tangle top, it seems likely that the disease would also be caused by injuries to the spindle by wind, farm labourers, and farm animals. It is quite evident that tangle top is unlikely to assume any economic importance and there is no occasion for alarm if a few cases are observed in a field.

Tangle top is reported as being present in Hawaii, Australia, Formosa, Philippines, Java, Louisiana, Cuba, and Porto Rico.

LIGHTNING INJURY (7).

Causal agency—Direct lightning strike.

APPEARANCE OF DISEASE. (Plate XV., Figs. 20 and 21.)

From time to time instances have been observed of circular areas in fields where the cane was affected with a top rot. This rotting was observed to follow periods of wet weather but could not be associated with any definite disease of the cane, nor did the affected areas appear to increase in size after the first few days. The symptoms shown by the individual canes affected with this form of top rot are as follows :—The young growing point is rotted and soft, with the result that the leaf spindle is easily removed. The leaves exhibit a purple discolouration on the exposed surfaces, wilt, and finally dry up. The top joints shrink rapidly as the rotting progresses downwards, reducing the tissues to a yellowish-evil-smelling slime. These symptoms are most pronounced at the centres of the diseased areas and grade off towards the margins. Shredded canes and small holes in the earth are occasionally found in these areas.

GENERAL REMARKS.

As a result of many observations it has been definitely concluded that this particular top rot is a direct result of the cane having been struck by lightning and killed or greatly weakened. It is obvious that nothing can be done to prevent this type of injury, and on the other hand it is unlikely that it ever assumes economic importance. Nevertheless its existence should be recognised in order that unnecessary alarm should not arise as a result of the sudden appearance of this condition of affairs in the cane field.

Occurrences of lightning injury have been reported from Hawaii, Java, Porto Rico, and Argentina.

DOWNY MILDEW.

Alternative names—Leaf Stripe, leaf-splitting disease, sclerospora disease.
Causal agent—*Sclerospora sacchari* Miy.

APPEARANCE OF DISEASE. (Plates XVI. and XVII.)

Downy mildew has two main diagnostic features, each associated with a different stage in the life history of the causal fungus, which enable it to be identified in the field —

(*a*) The leaves of the diseased canes bear light-green, or yellowish-green, stripes which at first glance may appear to bear a general resemblance to the symptoms of mosaic. A close examination shows that the markings are much longer and more regular and are not present on the unfolded leaves in the spindle, as in the case of mosaic. The streaks are numerous and range in width from a quarter of an inch upwards ; they are separated by narrow bands of normal green tissue, one-eighth to one-quarter of an inch wide, or they may be confluent, in which case the leaf is uniformly yellowish. On the lower surface of the leaves is a soft

white down which is composed of mycelium and myriads of spores of the causal fungus. On the older leaves the streaks become discoloured with reddish-brown spots and blotches, the tissue in the striped areas dies and turns brown, and the leaves tend to become torn and split along these lines of weakness. These symptoms are associated with the so-called conidial stage of the fungus.

(*b*) There is a pronounced elongation of some of the canes, as if they were about to arrow, causing them to stand out like flags some 2–3 feet higher than the neighbouring canes, and to be readily distinguishable from some distance. The elongated portion of the stem is extremely thin and the stem tissue is soft, watery, and brittle, while the leaves are stunted, sparse, and often highly coloured. In the winter these leaves wither and cling together and become split into shreds and twisted like rope. The freak flag-like tops and shredded leaves are associated with the oospore or resting spore stage of the fungus. The disease is an important factor on poor lands and badly tilled fields, it is most destructive on badly drained land and is worse on ratoon than on plant cane.

GENERAL REMARKS.

The disease is transmitted to healthy cane by means of the spores, which are wind-borne, and by this means the disease spreads from field to field with great rapidity. Under Queensland conditions infection takes place mainly during the rainy season (January to March): during the winter a large proportion of the diseased canes die out and the disease is very little in evidence from August to December. The oospore or leaf-shredding stage is best found during June and July. Control is effected mainly through the use of resistant varieties, and also through the selection of healthy seed and the burning off of the trash of diseased cane in order to destroy as many of the spores as possible. Apparently healthy cane cannot be considered as safe for seed if it is within about two hundred yards of diseased cane, as bud infection is common. In cases of very light infection, control can be obtained by roguing out the plants as soon as they exhibit symptoms of the disease.

Downy mildew is reported as being present in Fiji, Australia, and Formosa.

EYE SPOT (26, 27, 28).

Alternative name—Fire blight.

Causal agent—*Helminthosporium sacchari* Butl.

APPEARANCE OF DISEASE. (Plate XIV. Fig. 17.)

The first symptom is the appearance of small inconspicuous watery green areas on either surface of the leaves. In a very few days a watery green area becomes straw-coloured and elongated, with the long axis in the direction of that of the leaf, and is visible on both surfaces. The spots enlarge and develop reddish-brown centres within the yellow halo; at this stage they are about one centimetre long and have the appearance which is responsible for the name of "eye spot." With most varieties of

cane this represents approximately the ultimate stage of the development of the lesion, but with susceptible varieties the yellow halo elongates towards the tip of the leaf to form a straw-coloured streak, or runner, which later becomes a reddish-brown. Such streaks may be 18–36 inches long by one-eighth to three-eighths of an inch wide, not strictly uniform in width, and with an irregular outline. The coalescence of many streaks imparts a reddish colour to the leaf and a badly infested field has a reddish appearance, and hence the old name of "fire blight" was given to the disease. The tissue in the centre of the original spot usually dies and becomes an ashy colour. The lesions are practically confined to the leaf blades and are rarely found on the mid-rib or sheath. Under conditions very favourable to the disease the immature leaves in the spindle become infected, and from these the mycelium of the causal fungus penetrates to the growing tip of the cane, causing a top rot. The leaf streaks due to eye spot are sometimes confused with those of red stripe, but the latter are usually much narrower, have a darker purplish red colour, and are regular in outline and uniform in width. In the intermediate stages of the transition from the yellow to the reddish colour the eye spot streaks could sometimes be confused with those due to gumming.

GENERAL REMARKS.

Eye spot was described in Java nearly forty years ago and is to be found in almost every sugar country; nevertheless it did not assume economic importance until this decade, when epidemic outbreaks occurred in Hawaii and Porto Rico. In Hawaii the disease has been especially severe, in certain localities, on H. 109, which is an outstanding seedling of comparatively recent origin. Herein is an example of the obstacles confronting the breeder, inasmuch as any obscure disease may assume alarming proportions in the event of a susceptible seedling being bred. It is also a strong argument in favour of a very rigid quarantine. The spores are wind-borne and infection takes place during cool damp weather. In Hawaii, control is practised by avoiding late applications of nitrogen so that the cane is not making succulent growth during the danger period of low temperatures and high humidity. Early planting and the tapering off of irrigation water also assist in control. At present various dusts are being applied with a view to establishing another alternative method of control.

Eye spot is reported as being present in Hawaii, Fiji, Australia, Formosa, Philippines, Java, India, Mauritius, South Africa, Central America, Louisiana, Cuba, Santo Domingo, Porto Rico, British West Indies, Colombia, Brazil, and Peru.

RUST (4, 58).

Causal agent—*Puccinia kuehnii* (Kr.) Butl.

APPEARANCE OF DISEASE. (Plate XVIII.)

The leaves develop minute elongated yellowish spots, visible on both surfaces of the leaves. The spots later become brownish and on the under

side of the leaves are seen to be slightly raised above the surface, due to the formation of uredosori, or masses of uredospores. These sori rupture the epidermis and expose the orange-coloured masses of uredospores. Only the uredo stage has been found on sugar-cane, but the teleuto stage has been found on *Saccharum spontaneum* in Burma.

GENERAL REMARKS.

The disease appears to be confined to the Australian and Asiatic regions and has not yet assumed much economic importance. It is responsible for some damage in Queensland, and it is interesting to note that in Fiji it was found that rust was quite destructive on a number of seedlings which had been introduced from Hawaii. No special methods of control other than the use of resistant varieties have been devised.

Rust is reported as being present in Fiji, Australia, Formosa, Java, Philippines, and India.

RING SPOT (4, 23, 28).

Causal agent—*Leptosphaeria sacchari* van Breda.

APPEARANCE OF DISEASE. (Plate XIX.)

Ring spot may readily be found on the leaves of cane in most countries. The first symptom is the appearance of small purplish dots visible on both surfaces of the leaves. As the spots enlarge, the central tissue dies and becomes an ashy colour, surrounded by a reddish-brown band, beyond which is often an indistinct yellowish margin. The spots are roughly oval, a quarter of an inch long, irregular in outline, and frequently confluent. In the older spots the dead centre may bear a number of small black dots which are shown on microscopic examination to be the fructifications of the fungus. Ring spot is frequently confused with eye spot, but there are several differences which serve to distinguish the two diseases. In general, ring spot attacks only the older leaves, while the eye spot lesions are found on even the youngest leaves of the susceptible varieties: the margins of the spots are distinctly reddish in eye spot, as contrasted with the more brownish colour of ring spot; the spots are roughly oval in ring spot and elliptical and more slender in eye spot. Moreover there are considerable differences in varietal susceptibility, and so far there is no variety of cane on which ring spot produces the "runners" which are characteristic of eye spot on susceptible varieties.

GENERAL REMARKS.

Although widely distributed for many years, ring spot has never assumed economic importance, though it may do a little damage in moist localities. However, some years ago exactly the same sentence might have been written in regard to eye spot, but in the interim this disease has assumed epidemic form in Hawaii and Porto Rico. After many years of obscurity, eye spot suddenly sprang into prominence through the breeding of new seedlings which have proved highly susceptible in moist localities. Consequently we must always regard such diseases as ring

spot as being potentially dangerous and to be borne in mind by those supervising breeding programmes. A few of the newer Hawaiian seedlings show some susceptibility to ring spot, and the writer observed a few which showed numerous lesions on the fifth fully opened leaf; in these cases it seemed likely that material damage was being done to the plant.

Ring spot is reported as being present in Hawaii, Fiji, Australia, Philippines, Java, India, Mauritius, South Africa, Cuba, Porto Rico, British West Indies, Brazil, Argentina, and Peru.

BANDED SCLEROTIAL DISEASE (4, 58).

Causal agent—*Mycelia sterilia*.

APPEARANCE OF DISEASE. (Plate XX.)

This is probably the most easily recognisable of all the sugar-cane diseases. The first symptom is the presence on the leaves of irregular patches which are at first a dirty green, then brownish, eventually becoming pale yellow or white. They are visible on both surfaces. The size and shape of the individual patches varies greatly, but in general they tend to have their long axis across that of the leaf. The outline of the patches is sharply defined by a narrow reddish border. Patches are not usually confluent but separated by zones of green or brown leaf tissue. The disease is generally confined to the lower portions of the leaf blades but may sometimes be found on the leaf sheaths. Small hard black bodies, 1–3 millimetres in diameter, may be found on the under side of the leaves; these are sclerotia or resting bodies, and they retain their powers of germination over long periods of time.

GENERAL REMARKS.

Infection takes place from old cane leaves or grasses which bear the sclerotia, but the spread is very slow on account of the absence of a true spore form in the fungus. Where the disease is present all old leaves and vegetation should be burnt after harvesting.

The disease appears to be confined to Australia, Java, India, and the Philippines, but has never assumed economic importance in any one of these places.

BROWN SPOT (4, 23).

Causal agent—*Cercospora longipes* Butl.

APPEARANCE OF DISEASE.

The spots are found occurring on the immature leaves, as contrasted with ring spot, and persist throughout the life of the leaf. They are visible on both sides of the leaf and are confined to the leaf blades. The first symptom is the appearance of small reddish elongated spots, soon a brown centre appears and an irregular yellowish margin appears beyond the reddish band. Finally the spot is a deep brown with a deep ashy-coloured centre. The maximum size is 1–2 inches × an eighth of an inch;

spots are frequently confluent. The spots characteristic of eye spot are usually larger and more irregular and more numerous. Spores are formed on the ashy-coloured centres of the spots, and on the under surfaces of the leaves. Heavily infected fields have a general reddish appearance.

GENERAL REMARKS.

The disease is very common in India, where it is practically confined to the thin canes. No measures of control are known apart from the use of resistant varieties.

Brown spot has been reported as being present in India, Cuba, Porto Rico, British West Indies, and Brazil.

RED LEAF-SPOT (52, 58).

Causal agent—*Eriosphaeria sacchari* Went.

APPEARANCE OF DISEASE.

The spots are first visible as small red dots surrounded by a yellowish border, which later becomes reddish-brown, the yellow colour being reduced to a very narrow margin. The centre of the spot remains reddish and does not become dry and ashy-coloured as in the case of eye spot and ring spot.

GENERAL REMARKS.

This disease is of very minor importance and has been reported from Java and the West Indies. No definite measures of control are necessary at the present time.

YELLOW SPOT (52, 28).

Causal agent—*Cercospora kopkei* Krug.

APPEARANCE OF DISEASE.

The first sign of infection is the presence of large numbers of bright yellow spots on the upper side of the leaves; they are very irregular in outline and vary greatly in size. In the later stages of development the spots become dotted with red areas and occasionally the whole spot becomes reddish. In wet weather the under surface of the leaves may be covered with the whitish mycelium of the causal fungus.

GENERAL REMARKS.

As in the case of red leaf-spot this is a very minor trouble and has never assumed economic importance. At the present time it is fairly common in Java and the Philippines and has been reported from the West Indies.

MANGANESE CHLOROSIS (43, 46, 47).

Alternative names—Pahala blight, leaf-splitting disease.

Causal agency—A deficiency of manganese in the soil solution.

APPEARANCE OF DISEASE. (Plate XXI.)

The prominent symptom which is used for field diagnosis is the presence of long whitish longitudinal streaks upon the leaves. These streaks may be confined to a small number of individual leaves or involve most of the leaves of the cane top ; they are usually most pronounced on the third to the fifth leaves. The colour of the streaks may vary from an almost pure white to a sickly green, they are much more prominent at the base of the leaf than towards the tip. They follow the course of the vascular bundles and are caused by the lack of chlorophyll in the immediate vicinity of the minor veins ; the tissue surrounding the main veins usually remains green and may appear a darker green than normal. The streaks in the newly affected leaves are very narrow and well defined and are similar to the white streaks due to sporting (described under leaf variegation) but the streaks due to manganese chlorosis are much more numerous on the single leaf and are usually much narrower also. Moreover the streaks due to bud sporting are frequently confined to single leaves or to leaves on one side of the cane top. Manganese chlorosis may be distinguished from leaf-scald by the fact that in the former case the white streaks are confined to the leaf blade and do not extend on to the sheaths, nor is the production of side shoots stimulated as is the case with leaf-scald. On the older diseased leaves are found many rusty red streaks due to invasion by fungi and the complete breaking down of the tissues in the old chlorotic streaks. The leaves tend to split along these lines of weakness, and hence the name of leaf-splitting disease has sometimes been applied. This type of chlorosis is observed on soils which are alkaline or approximately neutral in reaction.

GENERAL REMARKS.

For a long period of time the following were considered as being the "essential" elements which must be present in the soil in order to permit of plant growth, viz., nitrogen, sulphur, phosphorus, potassium, calcium, magnesium, and iron. Recent work has demonstrated that while these are the only elements which must be present in any considerable quantity, yet there are several other elements, such as manganese and boron, of which slight traces must be present before a plant can attain its normal development. For many years the exact cause of this particular chlorosis was unknown, although methods for the complete control of the disease had been worked out. The recent work of McHargue and Lee has shown conclusively that the chlorotic condition of the leaves is due to an absence or insufficiency of manganese in the soil solution, due to the alkalinity of the soil solution. It is apparent from the work of these and other investigators that the presence of a trace of manganese is necessary for the full development of chlorophyll. In the course of their experiments

McHargue and Lee showed that the disease could be controlled by dusting the plants with manganese sulphate, mixed with sulphur as a carrier. The method of control which is successfully used by the plantations at the present time is that of sulphur fertilisation, the effect of the addition of the sulphur being to increase the acidity of the soil to a degree sufficient to bring manganese into solution.

Manganese chlorosis has only been reported from Hawaii, but this is probably the only country in which adequate investigations have been made along these lines.

LEAF VARIEGATION.

Leaf variegation is not a disease in the true sense, although in extreme cases there is no doubt that the very considerable loss of chlorophyll causes a pronounced dwarfing of the plants. By the term "leaf variegation" is meant the presence of sectors in which the colour differs from the normal green of the leaf. These areas may vary from a very thin almost imperceptible streak up to the stage where whole leaves, or even the whole cane top, may be involved. By far the most general form of variegated leaf is that in which the chlorophyll fails to develop and the affected areas are white instead of dark green. In certain varieties of cane, red streaks are also produced and these are of importance owing to their frequent resemblance to the streaks characteristic of red stripe and red streak diseases. In the case of variegated leaves, however, the streaks are usually found extending down on to the leaf sheath, which is not the case with red stripe and red streak. Narrow white variegated streaks are also similar to those typical of leaf-scald, and the confirmatory symptoms of leaf-scald must be sought before making a positive diagnosis. The streaks of red stripe, red streak, and leaf-scald definitely follow the course of the vascular bundles, while those due to variegation, if very narrow, tend to lie in between the major bundles. A cane in which variegation involves whole leaves, or whole cane tops, presents a very striking appearance, and in the latter case the affected plants are very markedly smaller than the surrounding canes.

GENERAL REMARKS.

These variegations or "bud sports" are known in genetics as sectorial chimeras. Their origin lies in a factor mutation in a single cell, but the causes underlying these mutations have never been determined. In general the width of the sector produced will depend on the stage of development in which the mutation took place. Where the variegation in colour is limited to a very thin leaf streak it is assumed that the mutation took place comparatively late in the development of the leaf, but if a whole leaf or a large proportion of the plant shows the variegation, it is assumed that the mutation took place in a region approximating very closely to the growing point. The condition of variegation is not infectious and does not occur sufficiently often to be of economic importance, but it would, of course, be unwise to plant sets from a cane which had all its leaves showing pronounced variegation.

SECTIONAL CHLOROSIS (19).

Alternative name—Cold chlorosis.

Causal agency—Environmental factors.

APPEARANCE OF DISEASE. (Plate XXII.)

Sectional chlorosis is the presence of colourless areas in the leaves, due to the inhibition of chlorophyll production during periods of unfavourably cold (and perhaps unfavourably hot) weather. The colourless areas consist of bands, 2-4 inches in length, and varying in width from a narrow marginal strip to a band stretching across the whole leaf. Apparently all the leaves which are in the spindle at the particular period of cold weather are affected in this manner, with the result that the bands are relatively higher on the younger leaves. That is, they are formed on the younger leaves before they have grown to their full length and so are carried upwards as the leaf elongates; the band on the youngest marked leaf is usually quite near the tip. The margins between the colourless and green tissue appear quite regular on a superficial examination, but a closer study shows that the two areas grade into one another. The larger veins usually retain their normal green colour.

GENERAL REMARKS.

This chlorotic condition is considered to be mainly due to the double effect of cold weather and the presence of water within the leaf cornucopia, thus causing the leaves to be chilled. The condition can readily be produced artificially by placing water in the spindle and then surrounding it with ice for some time. This condition has also been found in the green houses in Washington, D.C., and also has been observed in Southern Queensland during hot dry weather; thus it would appear to be associated with a variety of conditions. Naturally nothing practical can be done to avoid this trouble, but it is unlikely to assume economic importance.

ILIAU (17, 35).

Causal agent—*Melanconium iliau* Lyon.

APPEARANCE OF DISEASE. (Plate XXIII.)

The name "iliau" is derived from an Hawaiian word of which the approximate translation is "tight skin." The causal fungus invades the tissues of the leaf sheaths and binds or cements them together to form a hard unyielding cylinder which completely encases the growing tissues. The outer leaf sheaths and leaves are prevented from falling away in the normal manner and remain attached long after they are dry and dead. The leaf sheaths which have been killed by the fungus are a pinkish-brown colour, while the cane stem (if any has developed) is a deep bluish-grey. The imprisonment of the growing tissues, described above, effectively prevents the further upward growth of the cane, and the death of the growing point eventually follows. In efforts to continue upward growth the growing tissues frequently burst through the base of the cylinder of

cemented leaf sheaths, giving a twisted and buckled appearance to the stem. In favourable seasons a rapidly growing shoot will often "grow out" of the disease, that is, the growing point is carried beyond the zone of infection and can then continue unchecked growth. Such stalks can frequently be recognised by a few clinging discoloured leaf sheaths and the scarred stem. Infection takes place almost exclusively on the young shoots and is more severe on plant cane than on ratoons.

GENERAL REMARKS.

As stated above, iliau is primarily a disease of the young cane, and, while causing the death of large numbers of young shoots, may leave little trace of its presence when the cane is well grown. On the other hand it must be borne in mind that stalk counts have indicated that, even in perfectly healthy cane under normal conditions, up to 70 per cent. of the shoots produced die in the natural course of events. Therefore, unless the amount of infection is very great it appears unlikely that the disease will do much harm. Control is practised through the use of resistant varieties, early planting to ensure good growth before cool damp weather sets in, and good working of the soil to expose the fungus spores to the sun, under which conditions they are soon killed.

Iliau is reported as being present in Hawaii, Australia, Louisiana, Cuba, and Brazil.

RED ROT OF THE LEAF SHEATH (23, 58).

Causal agent—*Sclerotium rolfsii* Kruger.

APPEARANCE OF DISEASE. (Plate XXIV.)

This disease is an orange-red rot of the lower leaf sheaths, the area attacked being very irregular in outline and with indistinct margins. The attack is usually confined to the leaf sheaths which are within eighteen inches of the ground. The white mycelium of the causal fungus passes in to the inner leaf sheaths and binds them loosely together. Between the leaf sheaths, or along the edges, are formed the sclerotia which are small firm spherical bodies, ranging from yellow to brown in colour and from one–thirty-second to one-sixteenth of an inch in diameter.

GENERAL REMARKS.

The disease is very widely distributed in the field, but inasmuch as it is confined to the lower leaf sheaths it does no damage except, perhaps, that in the early stages of growth the leaf surface may be reduced somewhat.

Red rot of the leaf sheath is reported as being present in Hawaii, Fiji, Australia, Philippines, Java, Louisiana, Cuba, Porto Rico, British West Indies, and Brazil.

RED SPOT OF THE LEAF SHEATH (23, 58).

Causal agent—*Cercospora vaginæ* Kruger.

APPEARANCE OF DISEASE.

The characteristic feature of this disease is the production of bright red areas on the leaf sheaths. The first symptom is the occurrence of small

circular bright-red spots on the upper leaf sheaths, sharply delimited from the normal green of the surrounding tissue. As the spots increase in size they become irregular in shape, confluent, and finally cover most or all of the leaf sheath. The attack extends through to the inner leaf sheaths, the size of the area attacked becoming progressively smaller as it passes inwards. At times the invasion appears to extend right into the stalk; the leaves are not attacked. Black patches of varying size appear in the centres of the affected areas and the fructifications of the fungus are found in these areas.

GENERAL REMARKS.

The disease is widely spread, but probably does little damage and at all events attracts little attention. Experiments which were made in Porto Rico to determine the effect on germination were inconclusive. No methods of control have been devised, nor do they appear necessary.

Red spot of the leaf sheath is reported as being present in Java, Mauritius, Cuba, Porto Rico, British West Indies, and Brazil.

RED ROT (4, 23, 34).

Causal agent—*Colletotrichum falcatum* Went.

APPEARANCE OF DISEASE. (Plate XV., Fig. 19.)

In the field it is difficult to detect the presence of red rot from external appearances until the disease is well advanced. The first external indication is a loss of colour, wilting, and a dying back of the almost mature leaves, followed later by the older leaves and those in the spindle. The dying back of the leaves commences at the tip and proceeds back along the margins, the midrib and the adjacent tissue frequently remaining green for considerable periods of time. These symptoms may be exhibited by stools as a whole or by single canes of the stool. The wilted canes, when split open, show a very obvious discolouration of the internal tissues. In the early stages of the disease the internal tissue of the stem has an acid odour and shows a slight reddening in the basal internodes. The red colour is at first confined to the vascular tissue, but gradually invades the storage tissue, the periphery, however, remaining unaffected; it may be confined to a few internodes or may involve the whole stem. The colour is unevenly distributed, darker areas alternating with lighter-coloured areas; frequently there will be found dark red blotches with transversely elongated white centres, and these serve to identify the disease. At the outer edges the red blotches are sharply demarked from the surrounding healthy tissue. In the final stages the pith dries up and becomes a dirty brown mud colour, and there appear longitudinal cavities in which may be found the mycelium of the causal fungus. Externally the cane assumes a shrunken and wrinkled appearance, and in this condition there may sometimes be found small black tufts on the surface of the rind; these are the fruiting bodies of the causal agent. The final stages of red rot are often accompanied by rind disease, which is described elsewhere.

GENERAL REMARKS.

The disease is fairly readily found in most of the cane-growing countries of the world, but it assumes economic importance only in India and to a lesser extent in Louisiana and Australia. Infection of healthy canes appears to take place through wounds in the stalk, such as borer injuries, or through the delicate tissues of young buds, but it is unlikely that the latter mode of infection is a very important factor in the spread of the disease. In India, where epidemic outbreaks have occurred, it has usually been possible to trace the cause to the use of infected seed.

Under Queensland conditions complete control can usually be brought about by improved cultural methods ; the selection of healthy seed, and the rigid exclusion of all cane which shows a red discolouration at the cut ends, should also be practised. An important effect of the presence of the fungus is the reduction of cane sugar to glucose, decreasing the purity of the juice ; it follows therefore that the disease may cause considerable losses apart from the loss of tonnage due to the wilting of the cane.

Red rot is reported as being present in Hawaii, Fiji, Australia, Philippines, Java, India, Mauritius, Mexico, Louisiana, Cuba, Santo Domingo, Porto Rico, British West Indies, and Brazil.

WILT (4, 52).

Causal agent—*Cephalosporium sacchari* Butl.

APPEARANCE OF DISEASE.

The external symptoms are the same as those accompanying red rot and collar rot. In the early stages the internal tissue is diffuse purple or dirty red colour, with the colour tending to run in vertical lines. As contrasted with red rot the colour is not distributed in lighter and darker blotches, and any coloured areas never have transversely elongated white centres. The colour is not a bright red and soon becomes muddy. The pith dries up and forms cavities rather earlier than in the case of red rot. Brown patches on the rind indicate areas where the underlying tissue is dead.

GENERAL REMARKS.

Infection may take place through injuries in the stalk or through the tender tissues of leaf scars, root buds, etc., and this mode of infection appears to be the more usual type. Experiments have shown that the fungus cannot penetrate the uninjured rind ; leaves have been inoculated artificially, but cases of natural infection have not been observed. Following infection, the spread of the fungus within the cane is very slow. The disease has never assumed serious proportions ; the control measures are the same as those advised for red rot.

Wilt is reported as being present in the Philippines, India, South Africa, and the British West Indies.

COLLAR ROT (4).

Causal agent—*Hendersonina sacchari* Butl.

APPEARANCE OF DISEASE.

The external symptoms are the same as those exhibited by cane affected with red rot. The middle-aged leaves wither from the tips back along the margins, the midrib remaining green for considerable periods of time. On splitting the cane stalk it is seen that the tissue of the upper internodes is dry and pithy, with central cavities in some cases. The tissue of the lower internodes may be brown, with red streaks, especially marked at the nodes, while at the base of the stalk the tissue is a general red. In advanced cases the internodal cavities extend throughout the whole stalk. Roots arising from the basal nodes may be blackened and rotting.

GENERAL REMARKS.

This disease appears to be confined to India. Infection may take place through wounds and through the roots, the latter probably being the more important. The methods advised for control are the same as those advised for the control of red rot.

PINEAPPLE DISEASE (9, 23, 52).

Causal agent—*Thielaviopsis paradoxa* (de Seynes) v. Hohn.

APPEARANCE OF DISEASE.

This disease was so named on account of the fact that diseased cane has an odour which somewhat resembles that of pineapples ; it is widely distributed but rarely serious. The causal fungus also attacks the pineapple and the banana. The main characteristic of the disease is the presence of a sooty black core in the seed piece, composed of necrotic tissue and the macro spores of the fungus. This central black core serves to distinguish the disease from rind disease, the discolouration due to which is marginal. Pineapple disease is almost entirely a disease of the seed piece, but standing cane is sometimes affected during moist weather.

GENERAL REMARKS.

The infection of seed pieces takes place through the cut ends, probably after planting for the most part ; standing cane doubtless becomes infected through borer injuries. If germination is delayed on account of dry weather, or other causes, the set may become completely rotted by this disease and replanting will be necessary. As a measure of control the seed may be dipped in Bordeaux mixture and dried before planting.

Pineapple disease is reported as being present in Hawaii, Fiji, Australia, Philippines, Java, Mauritius, Mexico, Louisiana, Cuba, Santo Domingo, Porto Rico, British West Indies.

RIND DISEASE (22, 33.)

Causal agent—*Pleocyta sacchari* (Massee) Petr. & Syd. (*Melanconium sacchari* Mass.)

APPEARANCE OF DISEASE. (Plate XI., Fig. 14.)

The rind disease fungus is a very weak parasite and can only attack cane which has been injured or which is suffering from very unfavourable growing conditions. Consequently, rind disease is accompanied by symptoms of general ill-health of the cane, but these stand in the relation of cause rather than that of effect. On the outside of the stem are irregular dark discoloured areas, and on splitting the cane we find that the tissue immediately under the rind is also discoloured. As the disease progresses and the tissue becomes rotted the internodes become shrunken and wrinkled, and small eruptions, due to the development of the fruiting bodies of the fungus, appear on the discoloured rind. From these eruptions protrude long black coiled threads which are formed of countless numbers of spores. The fungus is quite common and is readily found on canes which have been cut and left lying in the field for some time.

GENERAL REMARKS.

The disease is widely distributed but is not found on otherwise healthy cane ; it may follow borer attack or may be found on cane which is over-ripe. Measures of control are unnecessary.

Rind disease is reported as being present in Hawaii, Fiji, Australia, Philippines, Java, India, Mauritius, South Africa, Mexico, Central America, Louisiana, Cuba, Santo Domingo, Porto Rico, British West Indies, Brazil, Argentine, and Peru.

STEM GALL DISEASE (37, 38).

Causal agent—Undetermined.

APPEARANCE OF DISEASE. (Plate XXV.)

The galls may be found upon either the nodes or internodes, but arise most commonly from the stem node and the root band ; in extreme cases the whole surface of the stem node and root band may be covered with galls. The galls which are formed on the internode proper appear to rise from the tissue between the striations or ridges on the rind. They are formed under the protection of the leaf sheaths, towards the growing point of the stem, and when first visible they resemble small thinly covered blisters, arising singly or in groups. As they develop they assume a variety of shapes but tend to be flattened owing to being confined by the leaf sheaths While some of these galls attain their maximum size without undergoing any apparent differentiation, many of those which arise from the nodes become differentiated into adventitious buds, some of which become exactly similar to the normal eyes, and, like them, can give rise to side shoots. Some of the differentiating galls may not proceed as far, and fail to develop a definite growing point, but give rise only to rudimentary leaf tissue. The younger galls dry up and turn brown when

exposed to the air by stripping off the leaf sheaths, but the remainder turn green and may enlarge considerably. One of the effects of the galls is to destroy all root buds, with the result that the cane is useless for seed on account of its inability to develop roots when planted. It has also been found that the injury known as knife cut is frequently associated with the stem gall disease.

GENERAL REMARKS.

The presence of galls or vegetative protuberances on the stems of cane has been noted from a number of countries, but owing to their very restricted occurrence they have been regarded purely as vegetative freaks. However, in Hawaii, in 1926, attention was directed to the fact that galls were occurring consistently, and with great abundance, on certain seedlings of Uba parentage. Very considerable damage was done to some of these seedlings and the necessity for an investigation to determine the true nature of this abnormal condition soon became apparent. At the present time the exact nature and cause are still unknown, although extensive inoculation experiments have failed to reproduce the symptoms and other experience suggests the non-infectious nature of the disease. In the meantime it is perhaps wisest to regard it as an infectious disease and take all appropriate precautions.

Stem gall disease is reported as being present in Hawaii, Fiji, Australia, Philippines, Java, Louisiana, and Cuba.

BUNGA (55).

Alternative name—Bulaklak.

Causal agent—*Æginetia indica.*

APPEARANCE OF DISEASE. (Plate XXVI.)

This is one of the very few cases in which a plant is actively parasitised by another flowering plant. *Æginetia indica* has neither roots nor chlorophyll of its own, and hence must depend on its host for its entire food supply. In cases of heavy infection the cane may be killed outright, but in all cases both the tonnage and the quality of the juice are reduced. The parasite attacks the roots of the cane, but is not evident above ground until the beginning of the dry season, when it send up a short stem at the base of the cane stool. This stem bears a few short scaly leaves and later sends up the conspicuous flowering stalks which are reddish in colour, with white stripes, and rarely more than 2 feet high. The flowers are somewhat pitcher-shaped and about 1 2 inches deep, light purple when young, becoming black when older, and give rise to vast numbers of very small yellowish seeds. Flowering usually takes place over a period of about four months, from autumn on till the middle of winter.

GENERAL REMARKS.

The seeds of *Æginetia indica* germinate only when stimulated by contact with the roots of a living plant. Apparently the roots of any plant

can provide the necessary stimulation, but penetration and parasitism of the root tissue only takes place when the seeds are in contact with the roots of certain members of the grass family. It has been found that the dried seeds retain their powers of germination for a period of about eighteen months. The newly germinated seedling is exceedingly small and consists of a very thin radicle, the plumule remaining undeveloped at this stage. If contact is not made with the roots of a suitable host this marks the limit of the growth of the seedling, but, on the other hand, if the radicle comes in contact with an appropriate member of the grass family, penetration is effected and the tip of the radicle swells to form a tubercle. The tubercle becomes differentiated into an haustorium and establishes organic connection with the conducting tissue of the roots of the host and the development of the plumule proceeds. The parasite is common in Japan, where it was first described, and is now a major parasite of cane in parts of the Philippine Islands. At the present time there is no knowledge of the relative resistance of the different varieties and the development of resistant varieties is likely to be difficult. In cases of very light infection it is recommended that the affected canes and the attached parasites be dug out and burned. Badly infected fields should be ploughed out and fallowed or planted to some dicotyledonous plant, such as a legume, for about two years. Lightly infected fields should be harvested as soon as possible, all trash burned, and the field planted to legumes, etc. Cane from infected fields should not be used as seed.

Æginetia indica has been reported as a parasite of sugar-cane from Philippines, Java, and India.

THE CANE-KILLING WEED (39, 53).

Alternative names—Witchweed, striga.

Causal agent—*Striga* spp.

APPEARANCE OF DISEASE.

The cane-killing weed is another example of a flowering plant which is found parasitic on the roots of sugar cane. The weed comprises several species of the genus **Striga**, all of which are parasitic. Cane which is attacked by these parasites is stunted and the leaves become dried and withered, the whole plant having a drought-stricken appearance. In cases of light infection there may be little damage to the cane, but in severe cases it is killed. At or near the bases of affected stools may be found the ærial stalks and flowers of the parasite ; it arises in clusters in very large numbers, and there may be as many as 15–30 shoots in the one plant. The height of the plant varies according to species. In Australia the average height is 6–9 inches, but in India *Striga densiflora* may be as high as 30 inches. The leaves are small, green, and lancet-shaped ; flowers are small, sessile, borne terminally in clusters, and vary in colour from white to light pink and light blue, according to species. In India the parasite first becomes visible above ground in the summer and flowers

during the autumn. The plant is a strict annual and, after flowering, both the ærial and underground portions dry up and turn black. The seeds are small and black and are borne in very large numbers in small capsules. On digging up a cane plant and the parasites it is found that the roots of both form a tangled mass, the roots of the latter being firmly attached to those of the former. The roots of the **Striga** species may be distinguished from those of the cane on account of their much lighter colour.

GENERAL REMARKS.

The life history of the parasites has not been worked out in complete detail. The seed probably germinates only in the presence of the roots of a growing plant : the roots of the seedling grow out and produce bell-shaped swellings, or haustoria, which apply themselves to the roots of the host plant and then put forth fine outgrowths which penetrate into the root tissues of the host. The early growth of the parasite is slow, and some time elapses before it appears above ground. The roots bear root hairs to some extent and thus it is likely that some moisture and nutrients are obtained directly from the soil as well as from the host plant. The leaves contain chlorophyll, which permits of photosynthesis, and thus **Striga** falls into the class of semi-parasites.

Serious losses of cane are sometimes caused by this parasite in parts of India where there are found two species, *Striga densiflora* and *Striga euphrasioides ;* in South Africa *Striga lutea* is a serious parasite of maize roots and also attacks cane. In Queensland we have three species or varieties which are unnamed as yet. Owing to the fact that the parasites are strict annuals the chief method of control is to uproot the plants before they have had time to flower and scatter the seeds. It is probable that the seeds can remain viable for considerable periods of time and hence, following heavy infection, it may sometimes be necessary to rotate to some crop such as legumes before replanting with cane.

Species of **Striga** have been reported as being parasitic upon sugar-cane in Australia, India, South Africa, and possibly the British West Indies.

THE ROOT ROT OR GROWTH FAILURE COMPLEX.

That very considerable losses are due to various diseases or diseased conditions of the roots of sugar-cane has long been recognised and it has been usual to refer to these troubles collectively as " root rot " or the " root disease complex." Root rots may arise from a variety of quite distinct causes, both infectious and non-infectious, but all have a common characteristic in the resultant failure of the cane to produce normal vigorous growth. For this reason there is now a tendency to refer to this subject as the growth failure complex rather than root rot. The study of the root diseases of cane presents many obvious difficulties and, experimentally at least, they have received far less attention than have

the diseases affecting other portions of the plant. Quantitative data as to the actual losses are lacking, but there is no doubt that most sugar men do not realise the magnitude of the aggregate loss of tonnage.

Systematic investigation of the so-called physiological diseases of roots, caused by unfavourable soil conditions, is only a recent study, but holds much promise on account of the introduction of the methods of modern physical chemistry to supplement those of purely inorganic chemistry which have prevailed in the past. As far as sugar-cane is concerned this type of investigation has not had wide application and the literature is very restricted. It is pleasing to note that in one or two experimental stations a determined effort is being made towards a comprehensive study of the question of nematode injury to the roots of sugar cane. Unfortunately, nematodes have always been regarded as a sort of scientific "no-man's-land," disowned alike by pathologists and entomologists—with the inevitable result that knowledge of the interrelations of these parasites with their hosts has advanced extremely slowly. In considering the infectious diseases of the roots one is confronted with a mass of literature; most of this, however, is composed of vague generalisations, unsupported by reliable experimental data, and serving to obscure rather than to clarify the situation.

The general symptoms of root diseases are those to be expected from malnutrition and a shortage of water; there is a failure to produce normal vigorous growth, a yellowing and premature death of the leaves, and a final wilting of the plant. These symptoms are more pronounced following periods of dry weather, that is, diseased cane fails to recover from drought after the manner of healthy cane. On examining the root system it is seen that the normal quantity of roots have failed to develop, while those roots which are present are stunted and often rotting.

It is the habit of many writers on the subject of root diseases to fix the responsibility on weak parasites and to conclude that all trouble will disappear with the use of better cultural methods. While this is doubtless very sound general advice, particularly in so far as the rots caused by weak parasites are concerned, it is apparent that improved cultural practices alone will not afford much relief when we are dealing with rots caused by active parasites or unfavourable mineral constitution of the soil. Each type must be dealt with according to its own peculiar needs, and thus it is imperative that the particular type or types under consideration should be recognised and classified. In this Key an attempt is made to sort out the salient facts of present knowledge and to arrange them so as to form a basis on which to distinguish these different types of root disease.

ROOT ROTS OF THE PYTHIUM TYPE (5, 6, 12, 31, 40).

APPEARANCE OF DISEASE. (Plate XXVII.)

By root rots of the pythium type we mean rots which are caused by active parasites, as opposed to those caused by weak parasites, and of the

former those caused by members of the genus **Pythium** are possibly the most important. The outstanding characteristic of the active parasites is their ability to invade not only the cortex but also to pass through the endodermis into the stele or central cylinder of the roots. These fungi are apparently able to enter the roots without previous injury to the host plant and commonly attack the tips of the roots, which become softened and watery in appearance. Red cankers appear as the rot first destroys the cortex and then passes in and destroys the stele. The result of the destruction of the stele is that the root loses its rigidity and becomes soft and flaccid to the touch. The rotting and destruction of the root tips causes a great reduction in the production of secondary or absorbing roots, as these are ordinarily formed at the growing tip. There is often an abnormal branching of the primary roots, in an effort to overcome the effects of the rot, and these form a decayed and dying cluster. As a rule badly affected plants are easily up-rooted.

GENERAL REMARKS.

Pythium has been reported as being associated with root rot in several countries, and its active parasitism has been demonstrated in Hawaii and the West Indies, although on Porto Rico and Barbados species of **Rhizoctonia** are reported to be more strongly parasitic. There is no doubt that there are several genera of fungi capable of producing this form of root rot and that the dominant fungi will be found to vary from country to country. Apart from the use of resistant varieties no definite means of control has been worked out for this group of diseases. Good æration appears to be a factor minimising the extent of the attack, and this is best brought about by constant and thorough tillage and drainage and sometimes by the adjustment of the replaceable base ratio. Some experiments have shown that the application of weak solutions of fungicides may prove a means of combating this and other diseases, but as yet the experiments have not been successfully conducted on a field scale, and no practical recommendations can be made.

Root rots of the Pythium type have been reported as being present in Hawaii, Java, Louisiana, Cuba, Porto Rico, and the British West Indies.

ROOT ROTS OF THE MARASMIUS TYPE (16, 18, 52, 54, 56).

APPEARANCE OF DISEASE.

Root rots of the **Marasmius** type are those caused by weak parasites which are only capable of entering and parasitising the roots after the latter have been weakened by unfavourable soil conditions or damaged by the small animal life inhabiting the soil. These rots are characterised by the fact that they affect the cortex only, and the fungi are apparently unable to penetrate the endodermis and destroy the stele or conducting tissue. The roots consequently retain their rigidity and do not become flaccid as happens in the pythium type of rot, where the stele is destroyed. A fungous rotting of the cortex of the older portions of the roots is accepted as a normal process and probably does little or no harm. When the plant

is weakened these fungi are enabled to enter the cortex of the young roots, causing a brownish-red rot, and destroying the growing tips of the primary and secondary roots. Abnormal branching of the roots follows and the tips of these branches are in turn killed, and as a result of the greatly reduced root system diseased stools are often very easily uprooted from the soil. Such fungi are often associated with a cementing of the lower leaf sheaths, a common occurrence in the rot caused by *Marasmius sacchari*, when the leaf sheaths are bound together by a white mycelium. In the later stages of the rot caused by *Marasmius sacchari* it is often possible to find the small mushroom-like fruiting bodies at the base of the diseased stools.

GENERAL REMARKS.

The fungi causing these rots are very numerous, and the association of **Marasmius**, **Rhizopus**, **Mucor**, **Odontia**, **Penicillium**, and **Fusarium** species is commonly reported. In Louisiana it is claimed that snails and centipedes are important agents in preparing the way for infection by these fungi, and in Hawaii nematodes, and to a certain extent various soil-inhabiting animals, are considered to act in the same manner. Probably the most frequent cause in the weakening of the plants and rendering them susceptible to attack is the compacting of the soil which follows poor cultivation, especially in the ratoon crops. This has no doubt been the cause of the so-called "running out" of many varieties in the past. The use of resistant varieties is advised, but efficient control of this type of rot can usually be effected by the practice of improved cultural methods, which keep the soil open and well ærated, and the suitable rotation of crops. The destruction of snails, centipedes, etc., by flooding or the use of soil fumigants is also recommended where feasible.

Root rots of the **Marasmius** type are reported as being present in Hawaii, Fiji, Australia, Java, India, Mauritius, Louisiana, Cuba, Porto Rico, British West Indies, and Argentina.

DRY TOP ROT (16, 41).

Alternative names—Vascular bundle disease, Plasmodiophora disease.
Causal agent—*Plasmodiophora vascularum* Matz.

APPEARANCE OF DISEASE.

The effect of this disease is to cause a wilting which, in field observations, is difficult to distinguish from the wilts due to several other causes. During favourable weather the external symptoms are not commonly noticeable, but they soon appear with the advent of dry weather. The first symptom is a loss of colour and a rolling and wilting of the leaves, then the dying of the tips of the central leaves, followed by the death of the uppermost portions of the canes. The resultant rotting of the tissues of the cane top is dry and not soft and evil-smelling. Frequently the drying of the leaves begins with one or more grey longitudinal stripes of dead tissue, about 1 centimetre wide, running down the centre of the blades of

the innermost leaves. Diseased canes fail to develop to the normal length on account of the upper joints being shorter and thinner than in healthy cane. On cutting across the base of a diseased cane the fibres appear lemon to orange red in colour, due to the presence of plasmodia and spores of the causal organism in the vascular bundles. This discolouration is usually confined to the lower and subterranean portions of the cane stalk and is characteristic of the disease. The disease is easily distinguishable from gumming, as there is no exudation of gum from the discoloured bundles.

GENERAL REMARKS.

The losses due to this disease may be heavy in dry weather, owing to the clogging of the vessels hindering the passage of the already reduced supplies of water. The causal agent has not yet been isolated in pure culture and so it cannot be said that the causal relationship of *P. vascularum* has been definitely proven. Transmission of the disease takes place mainly through the use of infected seed, but it can also be transmitted through the soil to healthy cane if the latter is planted in a field in which there has previously been a diseased crop. Control measures consist in the selection of healthy seed and in crop rotation. Seed should not be taken from a field which is known to contain diseased cane, in spite of the fact that the majority of the stools may appear quite healthy. Owing to the disease being confined mainly to the base of the cane stalk the use of top seed is advised when circumstances are such as to compel the use of seed from cane which is suspected of being lightly infected. As far as can be ascertained the sugar-cane plant is the only host of *P. vascularum* and therefore crop rotation to legumes and other crops will greatly aid in restoring "diseased" land to a condition where the planting of cane can safely be resumed.

Dry top rot is reported as being present in Porto Rico and the British West Indies.

GROWTH FAILURE AS A RESULT OF NEMATODE ("EEL WORM") INJURY (8, 11, 48, 49).

As has been said in the general consideration of the problem of growth failure, the detailed study of the inter-relations of parasitic nematodes and their hosts has been largely avoided by both pathologists and entomologists. This has particularly been the case as far as the study of the pests and diseases of sugar cane is concerned, and for the most part the literature contains but vague descriptions of the organisms or the damage for which they are responsible.

Within the last two years the staff of the H.S.P.A. Experimental Station has made a detailed and co-operative study of the general subject of growth failure, in which is included a systematic survey of the distribution of nematodes in the Hawaiian Islands, together with an inquiry into the damage done by each type and possible means of control. Similarly

intensive studies have not been undertaken by any other sugar experimental station, and this report is based on the work of the above institution, with which the writer had every opportunity to familiarise himself during the autumn of 1927. On account of the localisation of the studies it will readily be understood that the following remarks may not be strictly applicable to Australian conditions but rather indicate types of injuries and nematodes which must be sought.

APPEARANCE OF DISEASE AND CAUSAL ORGANISMS.

Cane attacked by nematodes exhibits no specific above-ground symptoms. In a field in which the infestation is heavy there is a retardation of growth and the cane has a generally indefinable "sick" appearance due to a slight yellowing of the leaves and a somewhat premature dying of the older leaves. When viewed from a distance such a field is often easily distinguishable from the adjacent healthy fields on account of the yellowed appearance of the leaves. The latter characteristic is frequently more locally marked in the case of infestation by **Heterodera** rather than by **Tylenchus.**

Nematodes, or eel worms as they are frequently called, are small round worms just too small to be visible to the naked eye. They may be either parasitic or saprophytic on the decaying organic matter of the soil, the latter type often being present in immeasurably large numbers. The parasitic genera are found within the cortex of the root, but may also penetrate the stele to a certain extent. In Hawaii it is found that the damage to the roots is caused mainly by three spear-bearing nematodes belonging to two genera, viz., *Tylenchus similis*, *Heterodera radicicola*, and *Heterodera schachtii*, each of which produce more or less characteristic lesions on the roots. Of the samples of sugar cane examined the roots of 85 per cent. have been found to be parasitised by nematodes, and of these approximately 55 per cent. contained *T. similis*, 20 per cent. *H. radicicola*, and 30 per cent. *H. schachtii.*

Tylenchus similis has been found on such a wide range of host plants as sugar cane, bananas, nut grass, pineapples, and pigeon peas, and thus there is little doubt that further investigation will prove it to be a parasite of many plants ; it usually lives its entire life within the roots of the host plant. It produces characteristically coloured lesions which are best seen on the newer roots after they have been thoroughly washed. These lesions first appear as small elliptic cinnabar-red-coloured areas, later developing a black centre which enlarges until finally the whole area becomes black on account of the complete degeneration of the cortex tissues. The attack is usually general throughout the whole field. The mature male of the species is rarely found on a microscopic examination of the roots ; the head is rounded and plain and constricted from the body by a definite suture, spear less prominent than that of the female and sometimes rudimentary ; a bursa is present and the tests are single. In the female the head is six-lobed, spear well developed, body has distinct striations,

vaginal opening is situated near the middle of the body ; gravid females do not become enlarged. The larval form is similar to the female in appearance.

From the external symptoms of the roots it is difficult to distinguish between the two species of **Heterodera** ; their chief characteristic is the formation of galls or swellings on the roots. These may be terminal on primary or secondary roots, or along the axis of the primary roots, and are often accompanied by an abnormal production of secondary roots. Both species are found in the axial swellings of the roots, but *H. schachtii* has never been found in the terminal galls ; on the other hand *H. schachtii* is found associated with a lignification and discolouration of the cortex but never *H. radicicola*. Both these species are commonly found near the point of junction of the secondary roots.

Heterodera schachtii.—The mature male is rarely found under natural conditions ; the head has a distinct six-lobed chitinous cap, spear large, striations on body distinct, testes single, bursa absent or rudimentary. The unenlarged female is very similar in appearance to the male ; vaginal opening is near the posterior end. The mature female becomes immobile, greatly swollen and flask-shaped, and contains many eggs and larvæ. The larvæ are very similar to the unenlarged females ; they may be distinguished from the larvæ of *H. radicicola* by the headpiece and from *T. similis* by the position of the gonads.

Heterodera radicicola.—The male is rarely found ; the head has no chitinous cap but is divided into three regions, spear slender, body striations not distinct, testes paired, bursa absent or rudimentary. The unenlarged female resembles the male in general appearance ; the vaginal opening is near the posterior end. The mature female becomes immobile, greatly enlarged and flask-shaped, and contains many eggs, but no larvæ, as contrasted with *H. schachtii*. The larvæ resemble the unenlarged females.

GENERAL REMARKS.

In addition to these three species there are a few others of minor importance. There are also vast numbers of saprophytic nematodes in the soil, but it is not considered that these are capable of doing any material damage to the cane. To a certain extent the nematode population appears to be restricted by natural enemies, such as fungi and other nematodes. The nematode *Mononchus* sp. appears to attack *Tylenchus similis* and the fungus **Microcera** attacks and kills the enlarged females of **Heterodera.** Owing to the fact that the three species pass practically the whole of their life within the roots it is not possible to destroy them by soil fumigation, but experiments are being carried out to determine the value of using fumigants on fallow land. Fallowing may be of value in reducing the **Tylenchus** population, but it unlikely to be of value in the case of **Heterodera,** as the latter is able to form a highly resistant cyst. So far the possibilities of the varietal resistance of different canes has not been determined nor has the value of a catch crop as a means of removing a large

proportion of the nematode population. The control as recommended at present is to make heavy applications of molasses or mud press and irrigate freely ; in other words, the application of any treatment which will increase the moisture and moisture-holding capacity of the soil. As a result of the greatly stimulated root development the plant is enabled to withstand the attacks of the nematodes.

Injuries to cane roots, due to nematode attack, have been reported from Hawaii, Australia, Java, Louisiana, Cuba, and Porto Rico.

MACROFAUNA INJURY TO ROOTS (54, 60).

Under this heading are considered the small soil-inhabiting fauna, other than nematodes, which attack the roots of sugar cane. For the most part the damage done by these animals is not, *per se*, of much consequence, but it assumes considerable importance as a possible factor in predisposing the roots to attack by fungous parasites, particularly by weak parasites of the **Marasmius** type.

APPEARANCE OF DISEASE.

The injury to the roots consists mainly in a pitting of the cortex : the lesions vary from well-defined pits to gross mutilations of the cortex, but rarely extend into the stele. With heavy infestation the pits may be crowded and confluent, causing the roots to present a honey-combed appearance. The pitting is often accompanied by reddish or watery rots of the adjacent tissues, due to invasion by fungi. The attack normally takes place in the region of the root tip, with the result that the growing points are often destroyed and the roots branch abnormally in an effort to restore the normal amount of root surface. The effects of the root mutilation are not readily apparent in the above-ground portions of the plant, but are nevertheless responsible for decreased yields when the numbers of animals is sufficiently high. Where extensive invasion by fungi follows the mechanical injuries the plants develop the symptoms of root rot, described on page 49.

GENERAL REMARKS.

The extent to which the attack of these animals predisposes the roots to attack by parasites is the subject of some controversy. In Hawaii, it would appear that they are not of importance in this respect, although one experiment showed greatly increased damage by **Pythium** when springtails were present in large numbers. On the other hand the work of Rands in Louisiana indicates that small soil-animals are a major factor in the root-rot problem of that State. It is probable that the relative importance of the various groups of soil animals will be found to vary greatly from country to country, but up to the present there have been comprehensive studies in only two countries. In Hawaii, the most important is a small springtail, *Isotomodes* sp., a small white insect of about one–twenty-fifth of an inch in length. Here the insect forms 48 per cent. of the animal life of the average cane field and averages about

800 per square foot to a depth of nine inches. Less numerous, and of much less importance, are two species of centipede, *Mecistocephalus maxillaris*, and one unidentified **Mecistocephalus** species, the former being somewhat larger, but present in smaller numbers than the latter. These two species together form 6 per cent. of the soil fauna ; both are brown in colour, and *M. maxillaris* is about one and a-half inches long when full grown, and has forty-eight pairs of walking legs, while the smaller species has thirty-six pairs of walking legs. These animals are carnivorous by nature and perhaps pit cane roots only to satisfy their need for moisture ; they make deep round pits which sometimes extend into the stele. While snails are considered to be responsible for only a negligible amount of damage in Hawaii the reverse is the case in Louisiana, where the small flat snail, *Zonitoides arboreus*, is considered to be extremely destructive. In addition there are two centipedes which mutilate the roots, *Arenophilus bipuncticeps* which is long, yellow, and thread-like, and *Hanseniella unguiculata* which is small and white and has twenty-four pairs of walking legs. The foregoing by no means represents a complete list of the root-attacking fauna, but merely records the more important types found in Louisiana and Hawaii and indicates types which may be expected in other countries.

It is generally agreed that most of these animals can feed on dead and decaying roots, and, in fact, prefer them as food. It is therefore evident that a scarcity of organic matter in the soil will tend to concentrate the attack on the roots of the living plants. Some hardy varieties of cane are much less affected by this form of injury, and much less susceptible to subsequent root rots, than are others, and control may be effected by the use of such varieties. In Louisiana it is found that the P.O.J. seedlings show these powers of resistance to a marked degree. A possible means of control is the use of soil fumigants, but investigations have not reached the stage where definite field practice can be advised ; in Louisiana promising experimental results have been obtained by applying paradichlorobenzene to fields of standing cane. An occasional flooding of the land has been found beneficial, but crop rotation does not appear to decrease the number of these animals to any extent. In Hawaii, experiments with soil fumigants have generally failed to give any satisfactory results, and the opinion is that the best means of control is by building up a high humus reserve ; the small animals then feed on the organic matter of the soil in preference to the growing roots.

Injuries to cane roots by soil-inhabiting animals other than nematodes are reported from Hawaii, Australia, Mexico, Louisiana, Cuba, and Peru.

GROWTH FAILURE DUE TO UNFAVOURABLE BASE RATIO (20, 21, 24).

APPEARANCE OF DISEASE.

The symptoms exhibited by sugar cane growing in soil in which the base ratio (*i.e.*, the ratio of calcium to magnesium and sodium) is unfavourable are, in common with the other types of growth failure, not capable

of precise definition. The writer saw a considerable amount of this trouble on the islands of Maui and Kauai, and from a superficial examination the symptoms appeared to be as follows :—The leaves lose their normal green colour and become yellowish, the tissue at the margins dies, giving the leaves a scalded appearance ; in extreme cases only the midrib remained green. The first stage in the yellowing of the leaves was the appearance of a broad chlorotic streak arising half way down the mature blade. Young shoots may retain their normal colour for some time and plant cane does not usually develop the chlorotic condition until it is a couple of months old. The growth is stunted and spindly, and in extreme cases the cane may die out completely ; the normal number of shoots fails to develop and consequently the stools are small and thin. Generally, this trouble occurs in small areas or " pockets," sharply demarked from the surrounding healthy cane in the remainder of the field. Upon an examination of the roots it is found that they are thin and dry and the quantity is very much below normal, due to the failure of secondary and tertiary roots to develop. On account of their weakened condition they are usually invaded by weakly parasitic fungi, bacteria, and nematodes, the cortex and sometimes the stele being badly rotted. The soils in which pronouncedly unfavourable base ratios are found are deflocculated and rubbery in texture, impervious to water and air, and thus unsuitable for the development of the normal quantity of roots. Unfavourable base ratios are common features of soils which have been irrigated with water containing a high percentage of dissolved salts, or soils which have been reclaimed from old sea beds, but may also be the natural condition of some virgin soils. In addition to the destruction of the physical texture of the soil, toxic effects are exerted by the magnesium and sodium in concentrations lower than those necessary to produce the extreme stage of deflocculation of the soil. All the symptoms described above may be exhibited by the cane while the soil is still in fairly good physical condition.

GENERAL REMARKS.

The elucidation of the problem of the cause of this type of growth failure has been made possible by the study of the " replaceable bases " of the soil. The term " replaceable bases " refers more particularly to the alkali metals sodium and potassium, the alkaline earths calcium and magnesium, and the ammonium radical, these being present in the soil in the form of their various salts—chloride, nitrate, sulphate, carbonate, phosphate, silicate, etc. It is considered that these salts exist in the ionised condition and that they are adsorbed on the surface of the clay, which constitutes the colloidal phase of the soil. An outstanding characteristic of the adsorbed replaceable bases is the firm manner in which they are held in the soil, and no amount of leaching out with pure water will remove appreciable quantities of them. On the other hand, leaching with a solution containing another base will immediately result in the removal of the adsorbed base, wholly or in part, depending on the concentration of the leaching solution. The base which was originally adsorbed on the colloidal surface is replaced by the base from the leaching solution and the

former then passes downwards with the gravitational flow of the water. For instance, if a soil which contains calcium in the replaceable form be leached out with a strong solution of sodium chloride the sodium replaces the adsorbed calcium and in turn becomes firmly fixed in the soil while the calcium drains out in solution as calcium chloride. The reaction is quite rapid, and the replacement more or less complete, if the concentration of salts in the replacing solution is relatively high.

It is well known to agriculturists that the presence of lime is necessary to preserve the tilth of the soil and that excess amounts of sodium, magnesium, and perhaps other bases, cause the clay to lose its granular structure and the soil becomes compacted. Consequently if the soil is one in which the percentage of clay is relatively high the presence of unfavourable amounts of these bases causes it to become very sticky and rubbery when wet, drying very fine and hard, and preventing the free passage of water and air to the roots. The constant use of irrigation water which contains high concentrations of sodium and magnesium will gradually bring about a replacement of the replaceable lime and eventually results in an extremely bad physical condition of the soil. In lands which have been reclaimed from the sea this exchange has been brought about by the concentrated solution of sodium chloride in the sea water. The condition of poor physical texture, produced in either of these ways, is always greatly increased by the subsequent use of pure water for irrigation purposes; this is due to the leaching out of the soluble salts which would otherwise help to maintain a certain amount of flocculation in the clay. In localities where this impermeable condition of the soil exists the tilth can generally be restored by a reversal of the process which brought about this undesirable condition, *i.e.*, by replacing sodium and magnesium with calcium. This may be done by the application of some form of lime and working it into the surface soil by cultivation. Owing to the ready solubility of calcium nitrate it is advisable to include a percentage of this form of lime in order to get some benefit as quickly as possible. Before the applications are made the amount of the replaceable bases should be determined by a chemist, who will advise as to the amount of lime necessary. The goal at which to aim should be a ratio of about five of replaceable calcium to one of replaceable magnesium and sodium. At the same time organic manures should be added in order to accelerate the restoration of the tilth.

Growth failure due to an unfavourable base ratio has been reported from Hawaii, Cuba, Porto Rico, British West Indies, and Brazil.

ALUMINIUM TOXICITY (42, 45).

NOTE.—There is a great divergence of opinion on the question of the existence of aluminium toxicity as such. Eminent workers claim that the toxic effects observed in the field are due to the unfavourable reaction of the soil and not to the presence of soluble aluminium and ferrous iron. That is, the acidity of the soil becomes a limiting factor before the soil solution is sufficiently acid to contain toxic amounts of aluminium and ferrous iron in solution. Comprehensive data on this aspect is lacking, and these notes are based on the only available evidence, *i.e.*, the experiments which were carried out in Hawaii.

APPEARANCE OF DISEASE. (Plate XXVIII.)

Another phase of the growth failure complex is the retardation of growth brought about by the toxicity of soluble salts of aluminium and ferrous iron, usually referred to as "aluminium toxicity." The symptoms exhibited by the affected plants consist in a shortening of the internodes and a stunting of growth, and the premature death and "firing" of the older leaves. The shortening of the internodes causes the leaves to lie close together, giving a fan-shaped effect to the cane top. Profuse production of ærial roots is common, these being long and fine in a humid atmosphere and short and stout under dry conditions. An examination of the underground roots frequently shows the cortex to be rotted. When the stem tissue is examined and stained according to the method of Hoffer, heavy deposits of aluminium are evident, especially at the nodes. This test should be made and compared with a test on healthy cane.

GENERAL REMARKS.

Since aluminium and ferrous salts are acid in reaction when in solution it is natural to expect that they would only be toxic in acid soils and, in general, aluminium toxicity is only a factor in soils of pH 5·8 and greater acidity. It is considered that these salts retard growth through their being taken into the plants in solution and then deposited in the vascular system, causing a mechanical clogging of the vessels and inhibiting the passage of plant nutrients. Where premature death of the leaves occurs it is found that abnormal quantities of aluminium are deposited in the vascular bundles at the junction of the leaf with the stem. The weakened tissues are rendered liable to attack by weakly parasitic fungi and such secondary rots are often found associated with aluminium toxicity.

It is quite impossible to get rid of the aluminium from the soil and, apart from the use of tolerant varieties, the principle of control is the conversion of the toxic salts into inactive insoluble compounds. There are at present three methods of control advised :—(1) The addition of lime to the soil until the reaction is neutral, when the aluminium will be insoluble ; (2) the addition of superphosphate to give the insoluble aluminium phosphate ; (3) the addition of large quantities of potash fertilisers. In some places a mixture of lime and superphosphate has been used successfully. Owing to the length of time necessary for chemical equilibrium to be attained in the soil it is not to be expected that these measures will produce immediate results.

Aluminium toxicity is reported from Hawaii, which is the only sugar-cane country in which the problem has been investigated.

SALT INJURY (44).

APPEARANCE OF DISEASE.

Growth failure of cane crops on account of salt injury is a condition frequently met in localities irrigated with artesian water, particularly in

soils which are alkaline or neutral in reaction. The symptoms are those of a general wilting, characteristic of a plant suffering from the effects of drought, together with a subsequent rotting of the root system. In severe cases even the stele of the roots may be rotted. Observations have been made of a plant growing in a water-logged soil and yet the leaves are wilted and rolled in and the plant is quite evidently unable to obtain sufficient water.

GENERAL REMARKS.

The cause of this particular type of growth failure arises from an unfavourable concentration of total mineral salts in the soil solution, usually due to excess of the chlorides of calcium, magnesium, and sodium. The varietal response of the cane varies very greatly, and the concentrations may at times be very high and yet exercise no adverse effect on varieties which are tolerant to this condition. In Hawaii, H. 109 may be seen growing well in an area in which the concentration of dissolved solids in the soil solution is much greater than that of sea water: the growth of Lahaina, on the other hand, is completely inhibited in this area.

It is a well known fact that a plant is enabled to take up water by virtue of the greater concentration of the root sap as compared with the soil solution. Water, or any other liquid solvent, always tends to flow from a region of less concentration to one of greater concentration and thus, under normal conditions, water tends to pass from the soil into the roots of plants. The cell membranes act as semi-permeable membranes which allow the free passage of water in either direction but allow the mineral salts to pass inwards only. From these considerations it will be seen that under some abnormal conditions the concentration of the dissolved solids in the soil solution may approach or equal that of the root sap, with the result that the osmotic flow of water into the roots is greatly reduced, or ceases, and the plant wilts. This has been termed physiological drought.

Owing to the large quantities of water lost by evaporation the heavy use of irrigation water containing large quantities of dissolved salts must quickly increase the concentration of the solids in the soil solution, particularly in badly drained land. Any measures of complete control must therefore include improved drainage followed by a leaching out of the soil, either by the aid of natural rainfall or the use of suitable irrigation water. In addition to the limitation of the available water the presence of excess amounts of calcium, magnesium, and sodium also reduce the amount of potassium which the plant can take up, thus causing potassium starvation. Owing to the difficulties of adequate leaching of many fields with highly concentrated soil solutions, it is apparent that relief must come mainly from the use of varieties which are tolerant of this condition of the soil.

Growth failure due to excessively high concentrations of salt in the soil solution have been reported from Hawaii, Java, Cuba, Santo Domingo, Porto Rico, and Brazil.

BIBLIOGRAPHY.

1. Artschwager, Ernst. Anatomy of the Vegetative Organs of Sugar Cane, Jour. Agric. Research, Vol. XXX., No. 3, pp. 197–221. 1925.

2. Bolle, P. C. Een Onderzoek naar de Oorzaak van Pokkahboeng en Toprot. Mededeelingen van het Proefstation voor de Java-Suikerindustrie. No. 15, 1927. Summary in English.

3. Brandes, E. W. Artificial and Insect Transmission of Sugar-cane Mosaic. Jour. Agric. Research. Vol. XIX., pp. 131–138. 1920.

4. Butler, E. J. Fungi and Disease in Plants. Thacker, Spink, and Coy., Calcutta and Simla. 1918.

5. Carpenter, C. W. Pythium in Relation to Lahaina Disease and Pineapple Wilt. Hawaiian Planters' Record, Vol. XXIII., No. 3, pp. 142–174. Sept., 1920.

6. ———. Morphological Studies of the Pythium-like Fungi Associated with Root Rot in Hawaii. Bull. of the Expt. Stn. of the H. S. P. A., Botanical Series, Vol. III., Part 1, pp. 59–65. Aug., 1921.

7. ———. Top Rot of Cane and Lightning Injury. Hawaiian Planters' Record, Vol. XXIV., No. 6, pp. 288–296. 1921.

8. Cassidy, G. H., and Van Zwaluwenburg, R. H. Nematodes in Relation to Growth Failure of Sugar Cane in Hawaii. Reports of Hawaiian Sugar Tech. Asson., 6th Ann. Meeting, pp. 10–15. 1927.

9. Cobb, N. A. Fungus Maladies of the Sugar Cane Expt. Stn. of the H. S. P. A., Divn. of Path. and Phys., Bull. No. 5, pp. 111–121. 1906.

10. ———. Third Report on Gumming of the Sugar Cane. *Ibid.*, No. 3. 1905.

11. ———. Estimating the Nema Population of the Soil. Bureau of Plant Industry, U. S. D. A., Agric. Tech. Circular No. 1. 1918.

12. Committee on Growth Failure Investigations. Reports on the "Root Disease Complex of Sugar Cane." Reports of the Hawaiian Sugar Tech. Assn., 5th Ann. Mtng., pp. 5–43, 1926.

13. Deerr, Noel. Cane Sugar. Norman Rodger, Altrincham. 1911.

14. Dormer W. C. & Wood E. J. F. Report on the Fiji Disease Situation in Queensland. Queensland Agric. Jour. Vol. XXVIII. Part 2, pp. 125–142. Aug. 1927.

15. Earle F. S. The Year's Experience with Sugar-cane Mosaic or Yellow Stripe Disease. Jour. of Agric. of Porto Rico, Vol. III. No. 4 pp. 3–35. 1919.

16. Earle. F. S. Sugar-cane Root Disease. *Ibid.*, Vol. IV., No. 1, pp. 1–27. 1920.

17. Edgerton, C. W. The Stem Rot or Hawaiian "Iliau" Disease of Sugar Cane. Phytopathology, Vol. III. No. 2, pp. 93–98. 1913.

18. ———. Taggart, W. G., and Tims, W. C. The Sugar-cane Disease Situation in 1923 and 1924. Louisiana Bull. No. 190. 1924.

19. Faris, J. A. Cold Chlorosis of Sugar Cane. Phytopathology, Vol. XVI., No. 11, pp. 885–891. 1926.

20. Hance, F. E. Base Replacement in its Relation to Hawaiian Soils. Reports Hawaiian Sugar Tech. Assn., 6th Ann. Mtng., pp. 30–33. 1927.

21. ——— & Stewart, G. R. Replaceable Bases in the Soils of Central Maui. Hawaiian Planters' Record, Vol. XXXI., No. 4, pp. 342–354. Oct., 1927.

22. Johnston, J. R. History and Cause of the Rind Disease of Sugar Cane. Jour. of Agric. of Porto Rico, Vol. I., No. 1, pp. 17–45. 1917.

23. ——— & Stevenson, J. A. Sugar-cane Fungi and Diseases of Porto Rico. *Ibid.*, No. 4. 1917.

24. Kelley, W. P., & Brown, S. Melvin. Replaceable Bases in Soils. Agric. Expt. Stn. of the Univ. of California. Coll. of Agric. Technical Paper, No. 13, pp. 33, Sept., 1924.

25. Kunkel, L. O. Studies on the Mosaic of Sugar Cane. Bull. of Expt. Stn. of H. S. P. A., Botanical Series, Vol. III., Part 2, pp. 115–167. Apr., 1924.

26. Lee, H. Atherton. Eye Spot Disease, Reports Hawaiian Sugar Tech. Assn., 5th Ann. Mtng., pp. 43–51. 1926.

27. ———, et al. Eye Spot Disease. A series of reports in the Hawaiian Planters' Record for 1925–7.

28. ———, & Martin, J. P. Description of Eye Spot as Compared with Other Sugar-cane Leaf Spot Diseases. Hawaiian Planters' Record, Vol. XXX., No. 4, pp. 470–1. Oct., 1926.

29. ———, & Jennings, W. C. Bacterial Red Stripe Disease of Tip Canes. Expt. Stn. of the H. S. P. A., Circular No. 42. 1925.

30. ———, & Staff of the Pathology Department. Red Stripe Disease Studies. H. S. P. A., Honolulu. 1925.

31. ———, Weller, D. M., & Barnum, C. C. Fungous Root Rots in Relation to Lahaina Growth Failure. Reports Hawaiian Sugar Tech. Assn., 5th Ann. Mtng., pp. 25–31. 1926.

32. ———. A Better Understanding of Pokkah Boeng and Twisted Top of Sugar Cane. Hawaiian Planters' Record, Vol. XXXII., No. 1, pp. 41–50. Jan., 1928.

33. Lewton-Brain, L. Rind Disease of the Sugar Cane. Expt. Stn. of the H. S. P. A., Divn. of Path. and Phys., Bull. No. 7. 1907.

34. ———. Red Rot of the Sugar Cane Stem. *Ibid.*, No. 8. 1908.

35. Lyon, H. L. Iliau, an Endemic Cane Disease. Expt. Stn. of the H. S. P. A., Divn. of Path. and Phys., Bull. No. 11. 1911.

36. Lyon H. L. Three Major Cane Diseases, Mosaic, Sereh, and Fiji Disease. Bull. of the Expt. Stn. of H. S. P. A., Botanical Series, Vol. III., Part 1. Aug., 1921.

37. ———. Galls on Sugar Cane in Hawaii. Hawaiian Planters' Record, Vol. XXX., No. 4, pp. 492–506. Oct., 1926.

38. ———. Further Notes on Stem Galls of the Sugar Cane. *Ibid.* Vol. XXXI., No. 3, pp. 249–273. July, 1927.

39. Luthra, J. C. Striga as a Root Parasite of Sugar Cane. Agric. Jour. of India, Vol. XVI., Part 5, pp. 519–523. 1921.

40. Matz, J. Investigations of Root Disease in Sugar Cane. Jour. of Agric. of Porto Rico, Vol. IV., No. 1, pp. 28–40. 1920.

41. ———. A New Vascular Organism in Sugar Cane. *Ibid.*, pp. 41–46. 1920.

42. McGeorge, W. T. The Influence of Aluminium, Manganese, and Iron Salts upon the Growth of Sugar Cane and Their Relation to the Infertility of Acid Island Soils. Bull. of Expt. Stn. of the H. S. P. A., Agric. and Chem. Series, Bull. No. 49. 1925.

43. ———. Pahala Blight and a Comparison with other Forms of Sugar-cane Chlorosis. Hawaiian Planters' Record, Vol. XXX., No. 2, pp. 293–328. April, 1926.

44. ———. Growth Failure on Soils Irrigated with Artesian Water. Reports Hawaiian Sugar Tech. Assn., 5th Ann. Mtng., pp. 31–34. 1926.

45. ———. Growth Failure on Acid Soils. *Ibid*, pp. 34–38.

46. McHargue, J. S. Manganese and Plant Growth. Jour. Indust. and Engineering Chem., Vol. XVIII., p. 172. 1926.

47. ——— & Lee, H. Atherton. The Effect of a Manganese Deficiency on the Sugar-cane Plant and its Relationship to Pahala Blight of Sugar Cane. In Press.

48. Muir, F. Nematodes considered in Relation to the Root Rot of Sugar Cane in Hawaii. Reports Hawaiian Sugar Tech. Assn. 5th Ann. Mtng., pp. 14–18. 1926.

49. ———, Henderson, Gertrude, & Van Zwaluwenburg, R. H. A Generic List of the Spear-bearing Nematodes, with a Revised Dichotomous Table. Hawaiian Planters' Record, Vol. XXXI., No. 4, pp. 351–361. Oct. 1927.

50. North, D. S. Leaf-Scald, a Bacterial Disease of Sugar Cane. Agric. Report No. 8., C.S.R. Coy., Sydney, 1926.

51. ———. The Dissemination of Gumming Disease. Australian Sugar Journal, Vol. XIX., No. 5, p. 285. 1927.

52. Nowell, W. Diseases of Crop Plants of the Lesser Antilles. The West India Committee, London.

53. Pearson, H. H. W. The problem of the Witchweed. Dept. of Agric. of South Africa, Bull. No. 40. 1921.

54. Rands, R. D. Root Disease of Sugar Cane in Louisiana, U. S. D. A. Departmental Circular No. 366. 1926.

55. Roxas, Manuel S. The Effect of "Bunga" (*Aeginetia indica*) on Sugar Cane at the Calamba Sugar Estate. Sugar News, Vol. VIII., No. 2, 1927.

56. Shepherd, E. F. S. Diseases of Sugar Cane in Mauritius. Mauritius Dept. of Agric., Bull. No. 32, General Series. 1926.

57. Storey, H. H. Streak Disease of Sugar Cane. Union of South Africa, Dept. of Agric. Science Bull. No. 39. 1925.

58. Wakker, J. H., & Went, F. A. F. C. De Ziekten van het Suikerriet op Java. E. J. Brill, Leiden. 1898.

59. Went, F. A. F. C. Does Sereh Exist in the West Indies, More Especially in Trinidad? West Indian Bull., Vol. XII., pp. 554–558. 1912.

60. Van Zwaluwenburg, R. H. Injury to Cane Roots in Hawaii by Soil Animals other than Nematodes. Reports Hawaiian Sugar Tech. Assn., 5th Ann. Mtng., pp. 18–25. 1926.

Plate I.

Gumming Disease. Coloured plate illustrating typical leaf streaks.

A. Upper portion of leaf of one-year-old Mahona showing characteristic leaf-streaks of gumming disease. The tissue in the older portions of the streaks is withered and in two instances has split longitudinally.

B. Top of stalk of one-year-old Mahona illustrating an advanced stage of the disease. Droplets of gum are oozing from the cut surfaces, and above are seen the reddened vascular bundles and two cavities filled with gum. Side shoots have been produced, and the rind has a shrunken, discoloured appearance.

This plate was prepared under the direction of Mr. D. S. North, and is here published for the first time, through the generous permission of the Colonial Sugar Refining Company, of Sydney.

Plate I.

A

B

Plate II.

Leaf Scald. Coloured plate illustrating typical leaf streaks on diseased Mahona.

A. and B. show the fine white pencil streaks. In A. the left-hand streak is becoming broad and diffuse.

C. Upper part of leaf showing the broadening and withering of old streaks which give the leaves the "scalded" appearance.

From Plate No. 1, Agric. Report No. 8, C.S.R. Co., Sydney.
(*Blocks supplied by the C.S.R. Co., Sydney.*)

Plate II.

A B C

Plate III.

Fig. 1—Cross section of leaf-blade, between midrib and margin. 8, 21, and 34, stomata or "breathing pores" of the leaf. 7, cell containing large numbers of chloroplasts. 11, one of the vessels of the xylem. 27, sieve tube of the phloem. 12, upper epidermis.

From Bull. 7, Fig. 3, Divn. of Path. and Phys., H.S.P.A.

Plate III.

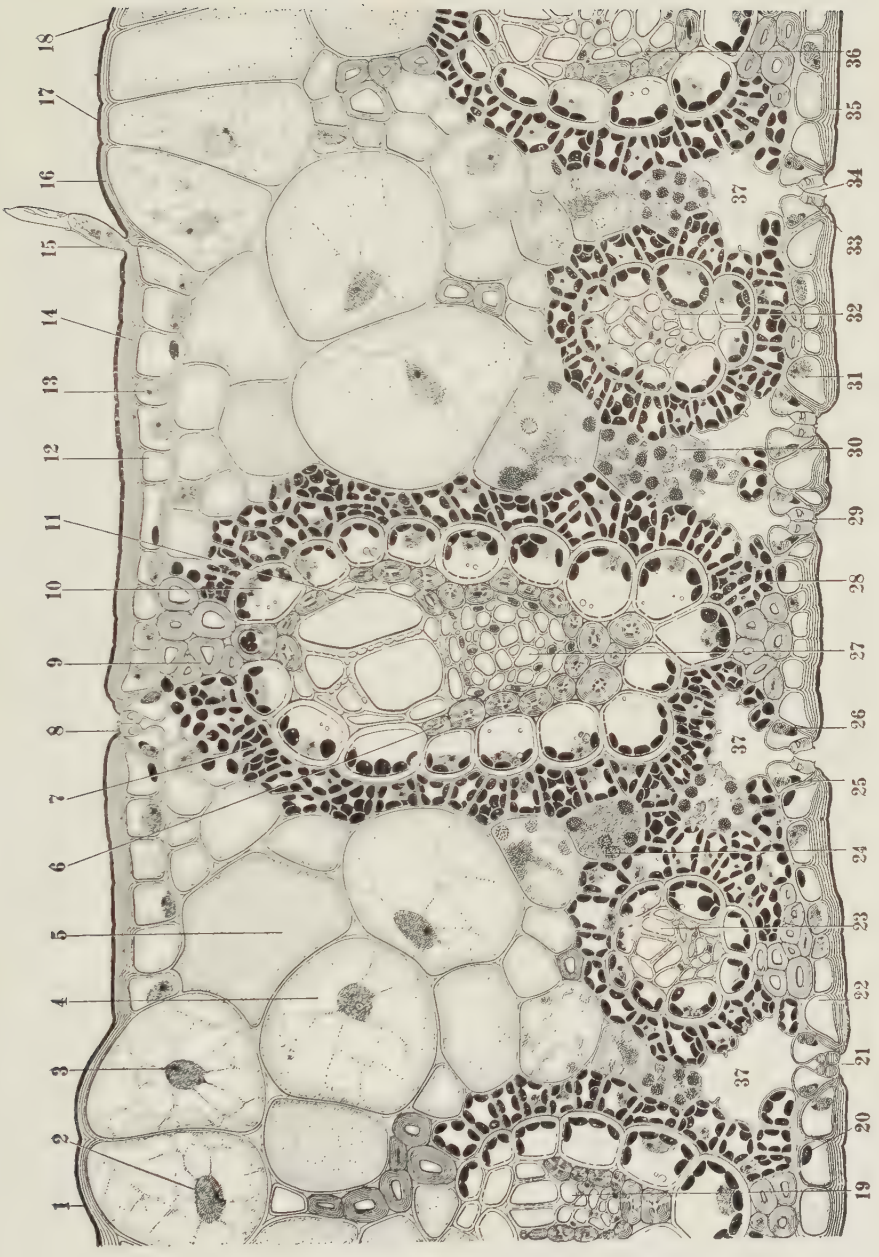

Fig. 1.

Plate IV.

Fig. 2—*Streak Disease.* Leaf from diseased plant of Uba variety, showing short, narrow, colourless streaks, running longitudinally – × 1.

Fig. 3—*Streak Disease.* As in Fig. × 2.

Fig. 4—Longitudinal section of end of a cane root; *rh*, root hairs arising from the epidermis. *Cor*, large soft cells of the cortex, extending from epidermis to endodermis. *st*, stele or central cylinder. *ro*, root cap.

From Bull. 7, Fig. 1, Divn. of Path. and Phys., H.S.P.A.

Photos. by H. H. Storey.

Fig. 2.

Fig. 3.

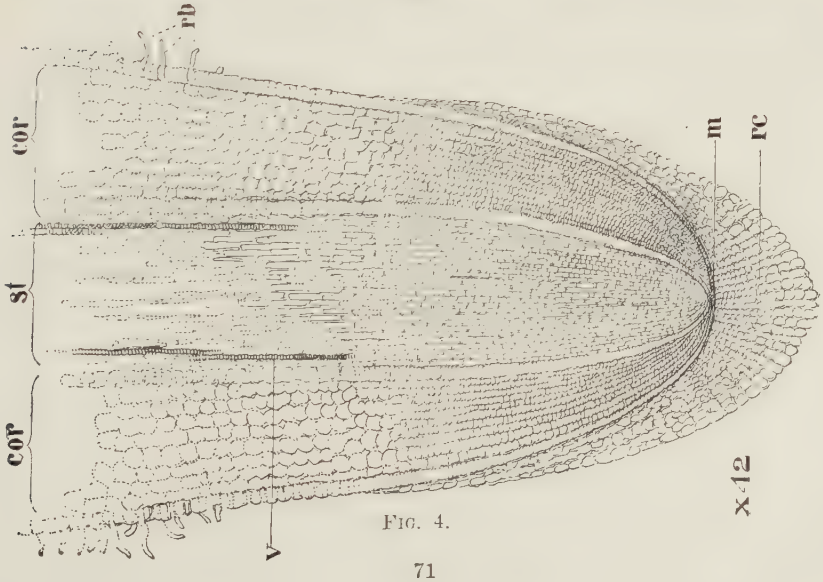

Fig. 4.

Plate V.

Fig. 5—*Streak Disease.* Healthy and diseased stools of Uba, 2½ months old.

Photo. by H. H. Storey.

Plate V.

Fig. 5.

Plate VI.

Fig. 6—*Fiji Disease.* A stick of E.K. 1 showing the typical symptoms.

Photo. by W. C. Dormer.

Fig. 6.

Plate VII.

Fig. 7—*Fiji Disease.* Stool of Badila cane, badly diseased but having one or two apparently healthy sticks.

Photo. by D. S. North.

Fig. 8—*Fiji Disease.* Portion of leaf of D. 1135 showing Fiji disease galls on lower surface.

Photo. by W. C. Dormer.

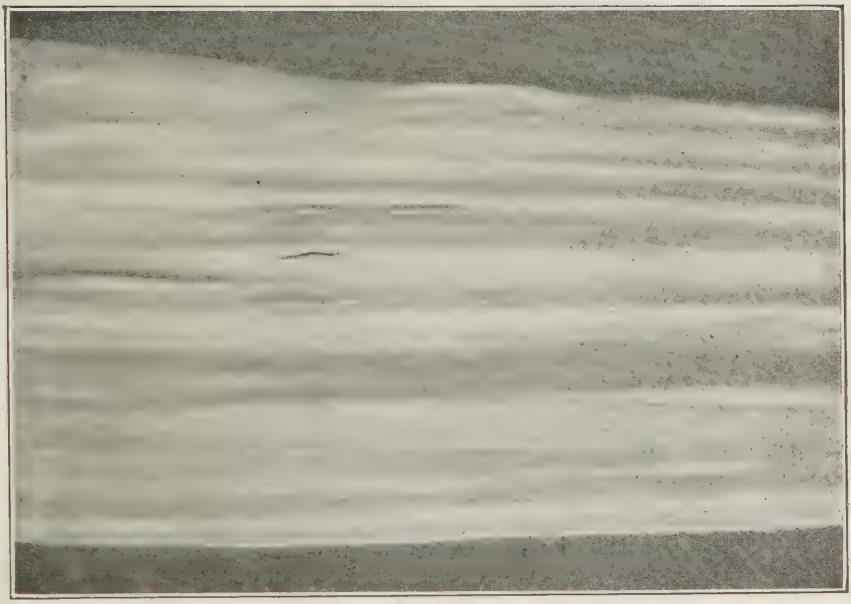

Fig. 8.

Fig. 7.

Plate VIII.

Fig. 9—*Leaf Scald.* One-year-old diseased Mahona showing the typical etiolated, withered, and curled-in leaves of cane top, as well as the production of side shoots.

Fig. 10—*Leaf Scald.* On right, feeble chlorotic shoots commonly arising when infected sets are planted. The fourth leaf of the plant second from the left bears a characteristic fine white pencil streak.

Photos. by D. S. North.

Fig. 9.

Fig. 10.

Plate IX.

Fig. 11—*Red Stripe.* Narrow red streaks on blade of leaf, following the course of the vascular bundles. The streaks may be seen coalescing, giving rise to comparatively broad bands.

Photos. by H.S.P.A. Experiment Station.

Plate IX.

Fig. 11.

Plate X.

Fig. 12—*Sereh.* Ten-months-old diseased Cheribon, in foreground, compared with healthy cane of same variety and same age.

From Bull. Expt. Stn., H.S.P.A., Vol. III., Part 1, Fig. II.

Plate X.

Fig. 12.

Plate XI.

Fig. 13—*Sereh.* Stick of B. 247 showing production of aerial roots.

From Bull. Expt. Stn., H.S.P.A., Vol. III., Part 1, Fig. 9.

Fig. 14—*Rind Disease.* *b*, small black pustules or eruptions on rind of diseased cane from which arise the long, coiled, hair-like spore masses *c*.

From Bull. 7, Fig. *b*, Divn. of Path. and Phys., H.S.P.A.

Plate XI.

Fig. 13.

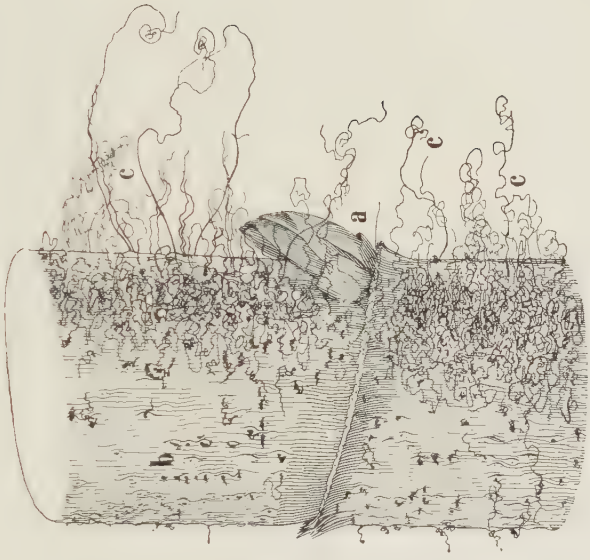

Fig. 14.

Plate XII.

Fig. 15—*Pokkah Boeng.* Ladder-like lesion and brown streak in stem of diseased cane.

Drawn by I. W. Helmsing.

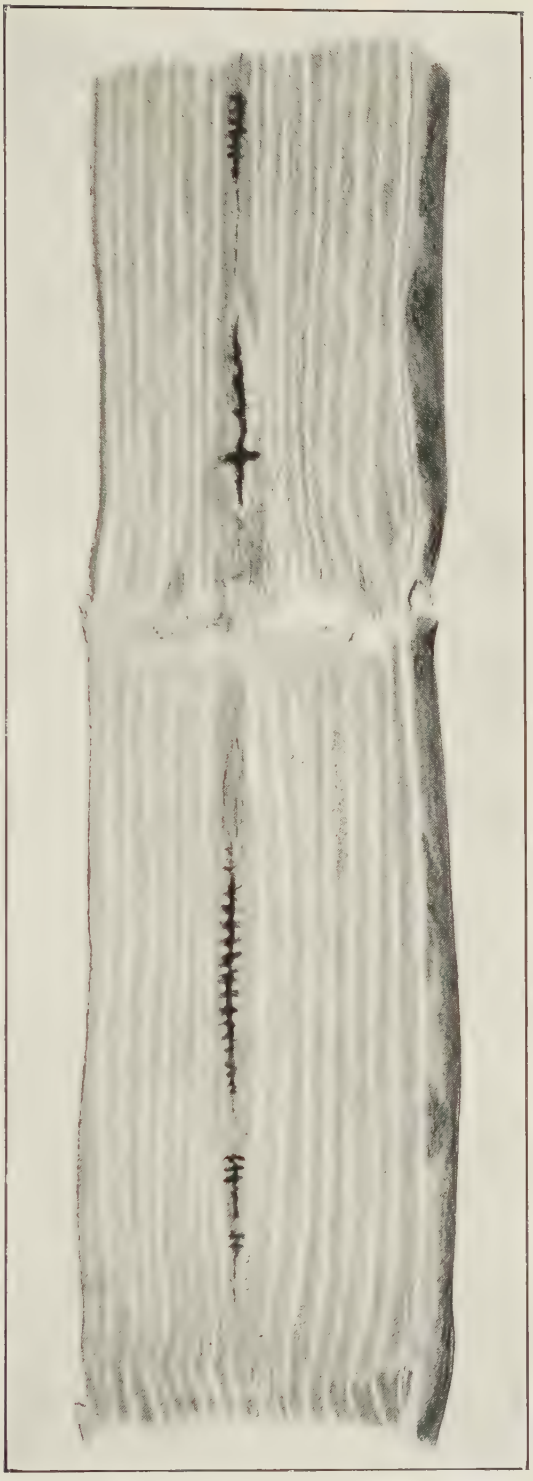

Fig. 15.

Plate XIII.

Fig. 16—*Smut.* On Luzon White, showing long black whip-like appendage arising from apex of cane.

Photo. by Phil. Bur. Sci.

Plate XIII.

Fig. 16.

Plate XIV.

Fig. 17—*Eye Spot.* Youngest spots, towards top figure, have an appearance resembling the eyes on a peacock's tail; the older spots have developed runners.

Photo. by H.S.P.A.

Fig. 18—*Tangle Top.* Naturally occurring case of tangle top in H. 109.

Photo. by H.S.P.A.

Plate XIV.

Fig. 17.

Fig. 18.

Plate XV.

Fig. 19—*Red Rot.* Advanced stage of disease; at X, X, X are the transversely elongated white areas in the middle of the red blotches.

From. Bull. 5, Fig. 1, Div. of Path. and Phys., H.S.P.A.

Fig. 20—*Lightning Injury.* Stripping effect of lightning shown on cane in foreground; this cane was stripped of its foliage and a trench 8 inches deep extended out from the base of the stool.

Fig. 21—*Lightning Injury.* Top rot and shredding of leaves as a result of lightning injury. Section through cane on right shows cavities in stem.

Photos. by H.S.P.A. Experiment Station.

Fig. 19.

Fig. 20.

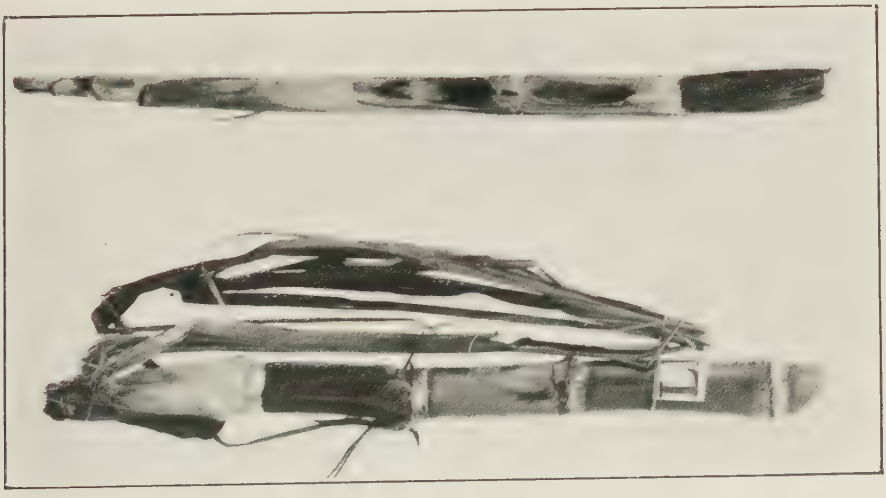

Fig. 21.

Plate XVI.

Fig. 22—*Downy Mildew.* Lower surface of leaf blade, showing the "downy mildew" stage of the disease; this is due to the profuse production of conidia by the causal fungus.

Fig. 23—*Downy Mildew.* Twisted and shredded leaf from elongated or flag-like top of diseased cane. The oospore stage of the causal fungus is found in this type of leaf.

Photos. by D. S. North.

Plate XVI.

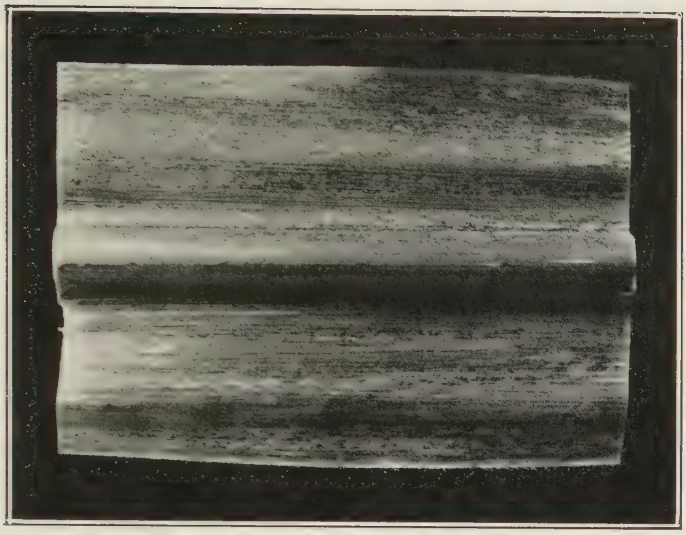

Fig. 22.

Fig. 23.

Plate XVII.

Fig. 24—*Downy Mildew.* Elongated tops or flags of diseased canes, which appear during the winter and are associated with the oospore stage of the causal fungus.

Photo. by D. S. North.

Plate XVII.

Fig. 24.

Plate XVIII.

Fig. 25—*Rust.* Small elongated slightly raised brownish spots on under surface of leaf.

Photo. by Phil. Bur. Sci.

Plate XVIII.

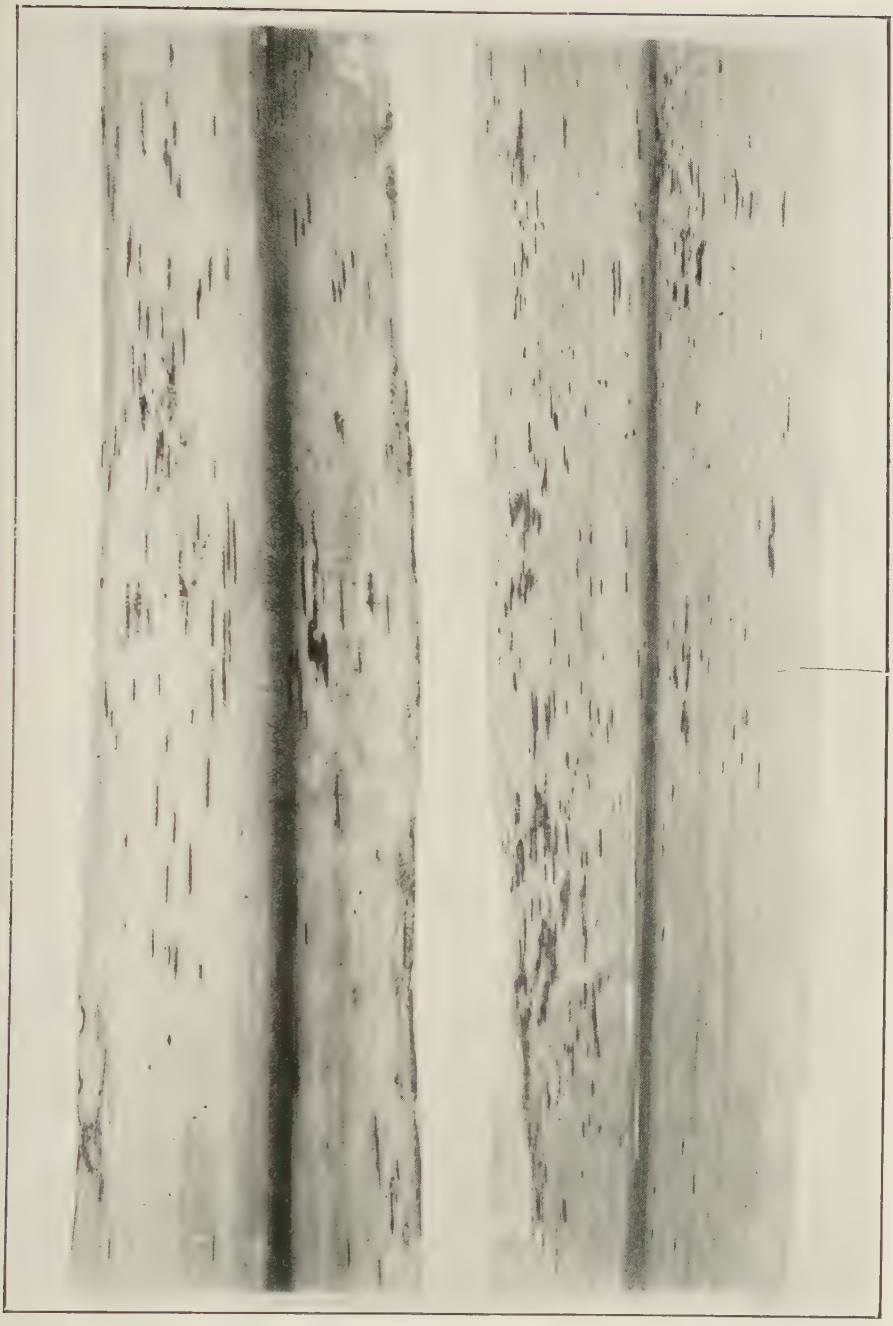

Fig. 25.

Plate XIX.

Fig. 26—*Ring Spot.* Spots are roughly circular, older spots having ashy coloured centres with reddish-brown margins.

Photo. by Phil. Bur. Sci.

Plate XIX.

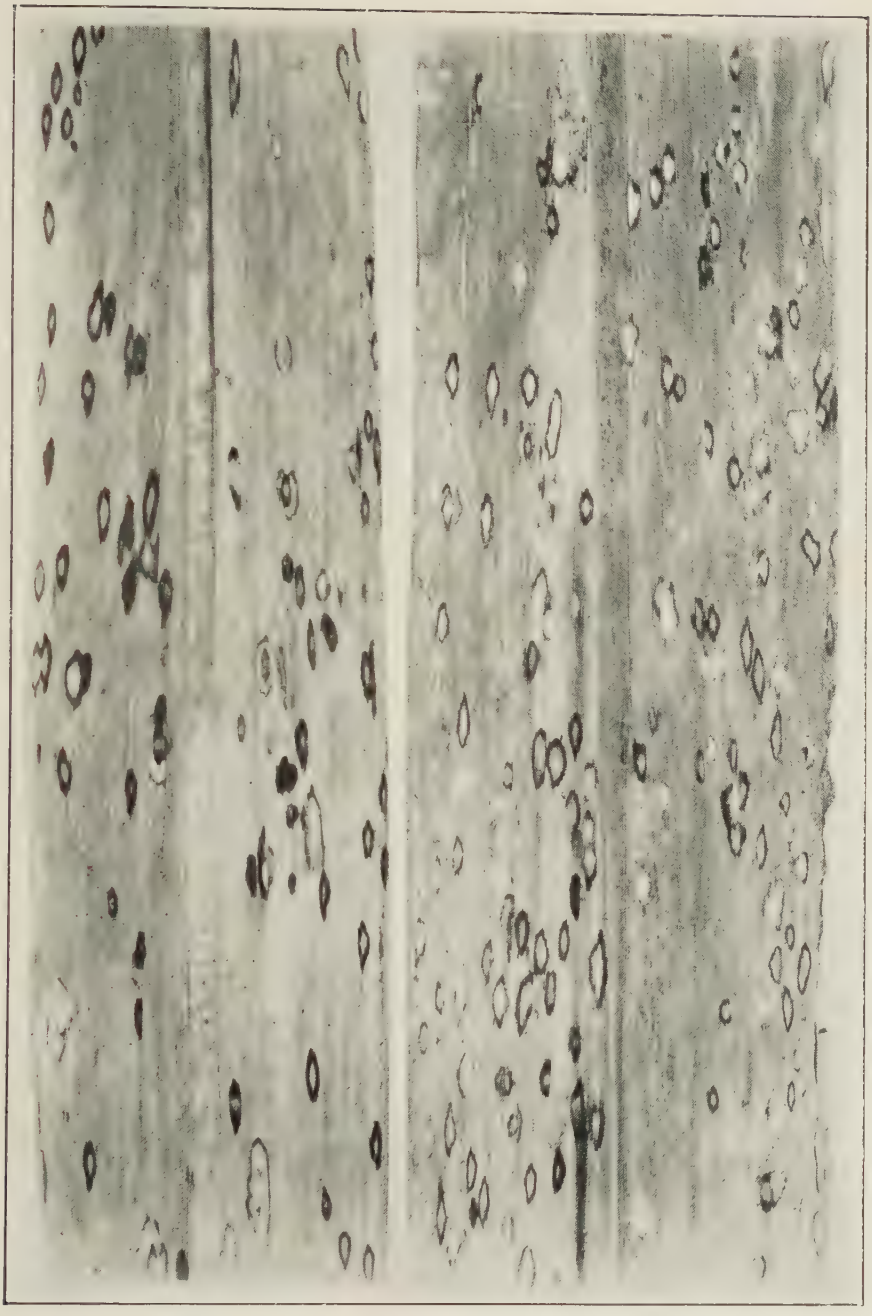

Fig. 26.

Plate XX.

Fig. 27—*Banded Sclerotial Disease.* Irregularly coloured and irregularly shaped bands on the blades of the leaves.

Photo. by Phil. Bur. Sci.

Plate XX.

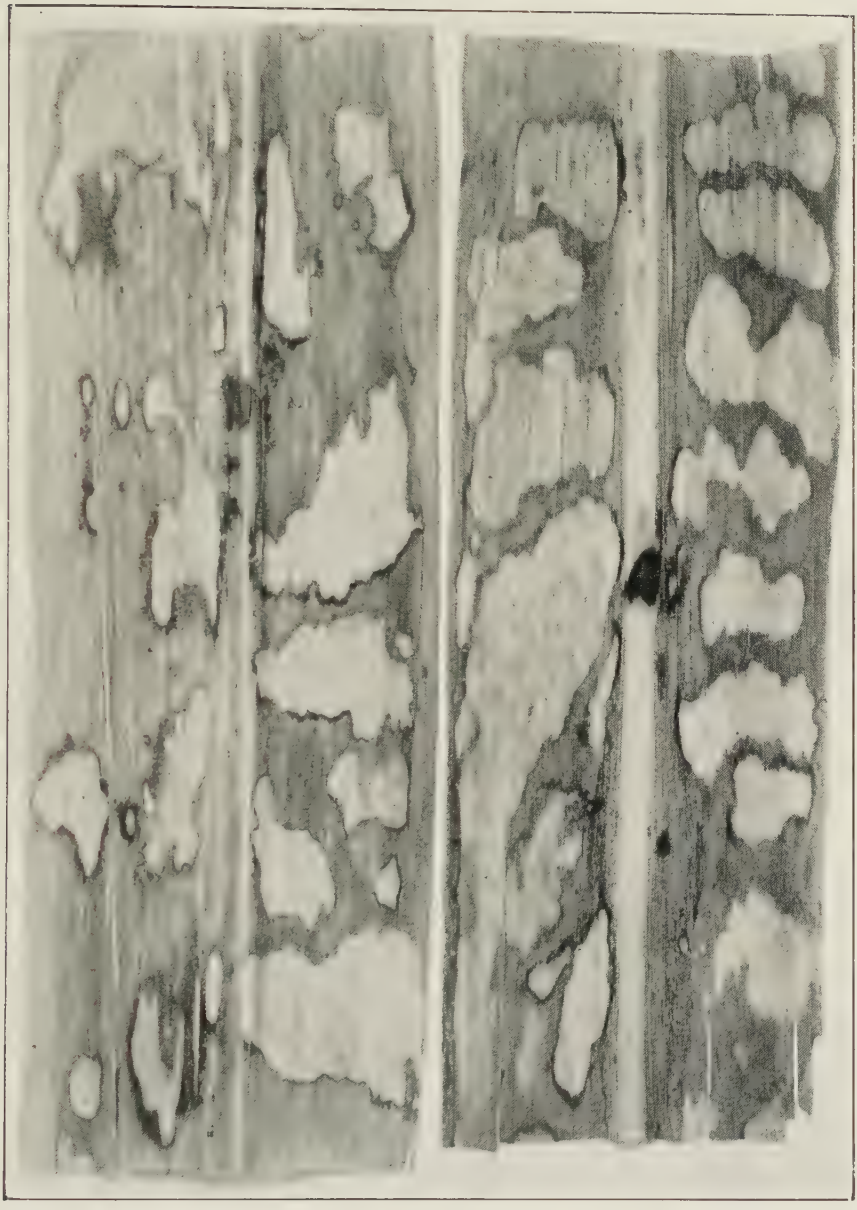

Fig. 27.

Plate XXI.

Fig. 28—*Manganese Chlorosis.* Parallel white lines on leaf blades, due to failure of chlorophyll to develop in consequence of deficient manganese in the soil solution.

Drawn by I. W. Helmsing.

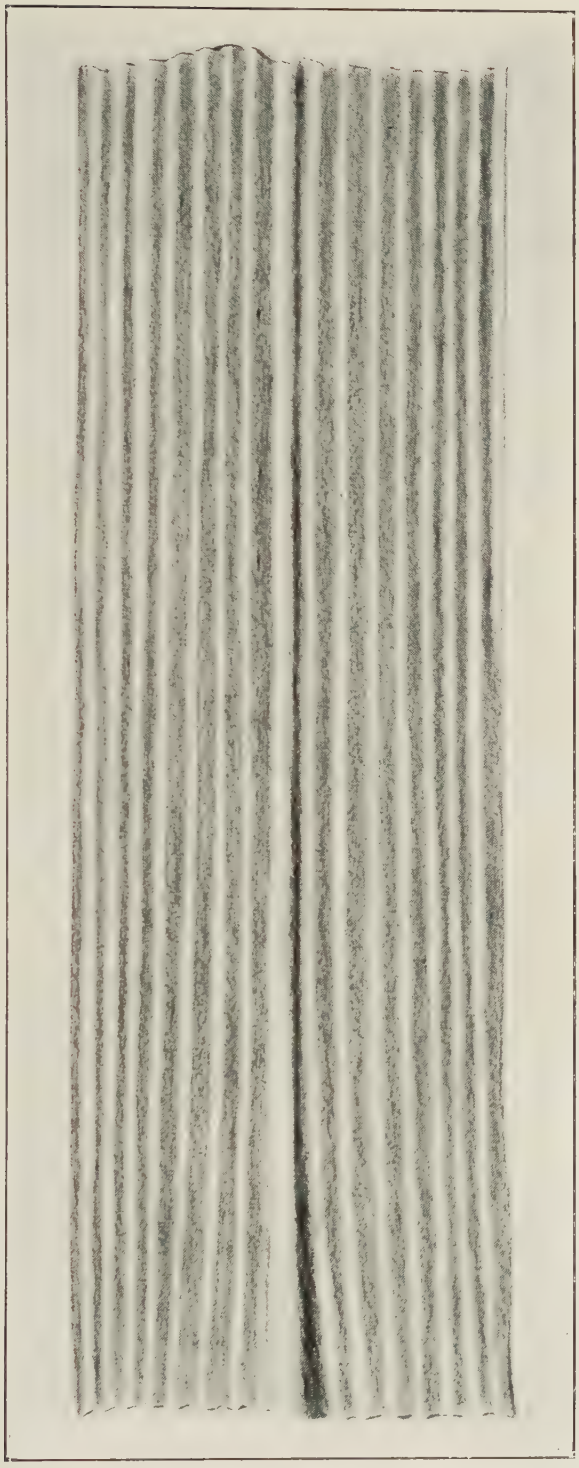

Fig. 28.

Plate XXII.

Fig. 29—*Sectional Chlorosis.* Top of cane affected with sectional chlorosis, showing the relative positions of the white bands on young and old leaves.

Photo. by H.S.P.A. Experiment Station.

Fig. 29.

Plate XXIII.

Fig. 30—*Iliau.* Young diseased cane firmly encased in a jacket of cemented leaf sheaths. In efforts to continue upward growth the shoot has become buckled and has burst out through the leaf bases.

From Bull. 11, Fig. 10, Path. and Phys. Series, H.S.P.A.

Plate XXIII.

Fig. 30.

Plate XXIV.

Fig. 31—*Red Rot of the Leaf Sheath.* The small pinkish fruiting bodies (sclerotia) of the causal fungus may be seen along the edges of the leaf sheaths.

Photo. by Phil. Bur. Sci.

Plate XXIV.

Fig. 31.

Plate XXV.

Fig. 32—*Stem Gall.* Variety U.D. 47. Galls on and above the growth rings, with striate proliferations on the internodes; wax is absent from the more seriously affected parts of the internodes.

Photo. by H.S.P.A.

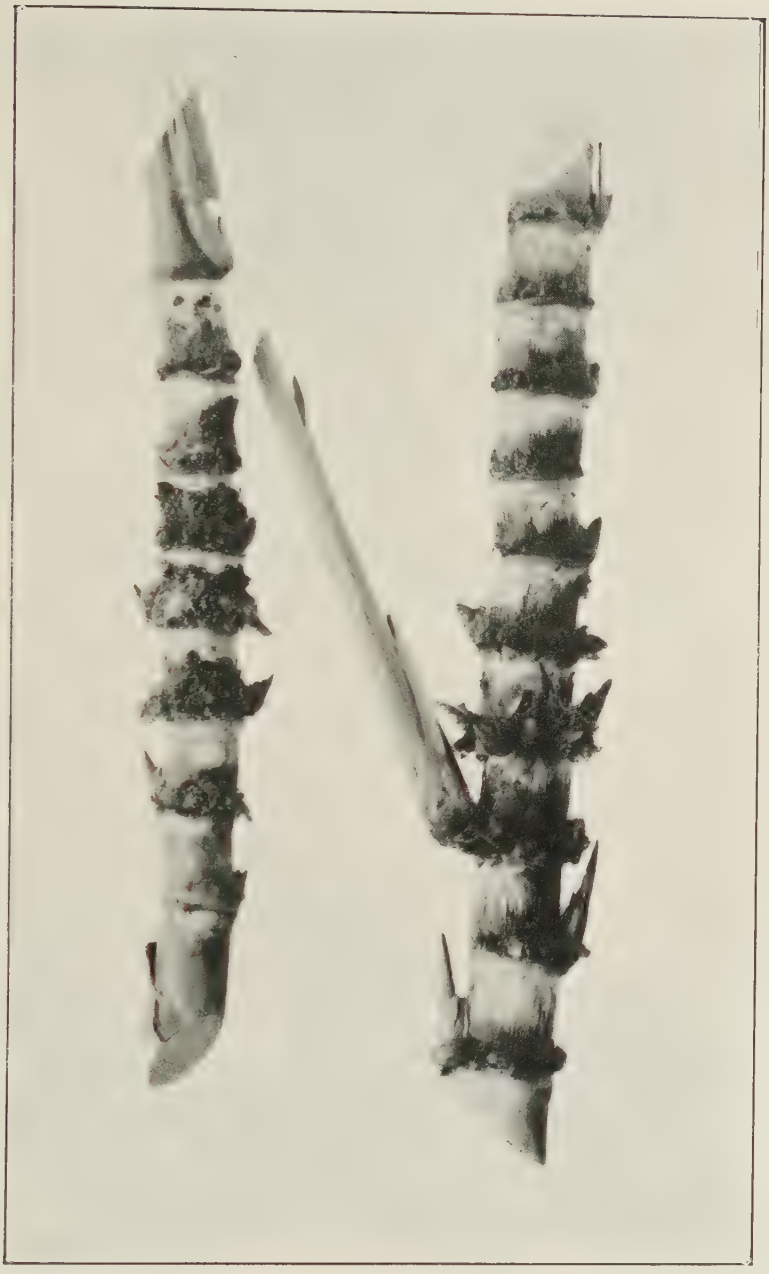

Fig. 32.

Plate XXVI.

Fig. 33—*Bunga.* Cluster of floral stalks and flowers of *Aeginetia indica,* showing attachment to cane roots.

Fig. 34—*Bunga.* Plant of *Aeginetia indica* growing at base of cane stool.

Photos. by Phil. Bur. Sci.

Fig. 34.

Fig. 33.

Plate XXVII.

Fig. 35—*Pythium Root Rot.* Below, normal turgid roots; above, flaccid roots due to the destruction of the stele by *Pythium*.

Photo. by H.S.P.A. Experiment Station.

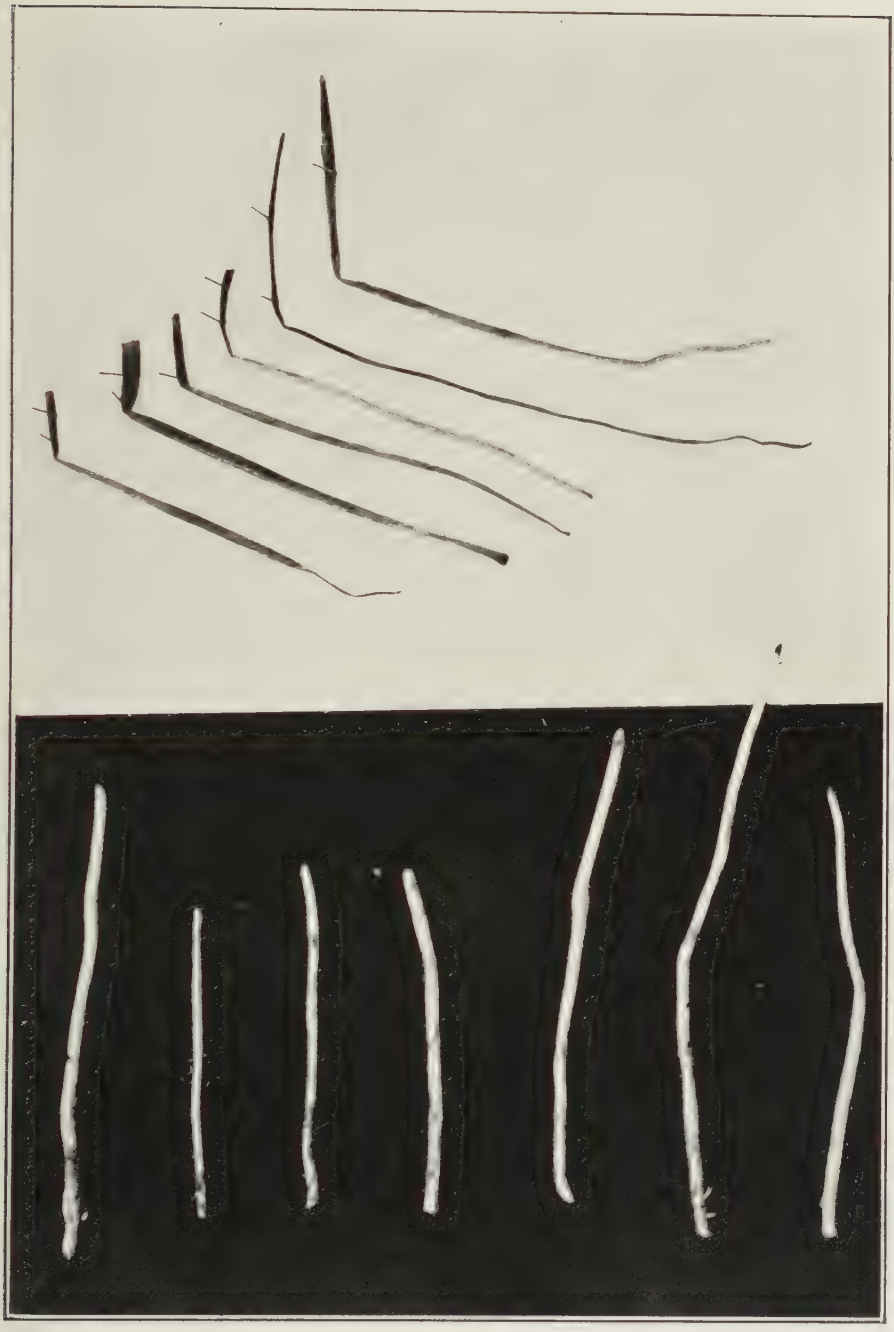

Fig. 35.

Plate XXVIII.

Fig. 36—*Aluminium Toxicity.* Longitudinal section of stem showing positive hæmatoxylin test for accumulations of iron and aluminium at the nodes.

Fig. 37—*Aluminium Toxicity.* Longitudinal section of stem of Lahaina; note shortening of internodes and tapering of top.

Fig. 38—*Aliminium Toxicity.* Production of aerial roots on a diseased cane; these roots are long and thin under humid conditions and short and stout under dry conditions.

Photos. by H.S.P.A.

Plate XXVIII.

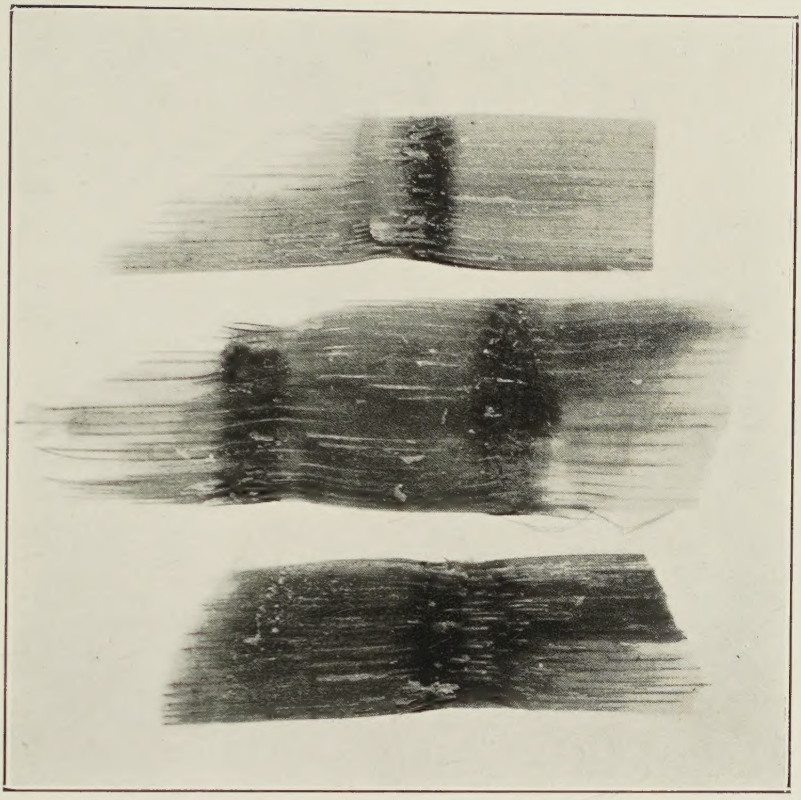

Fig. 36.

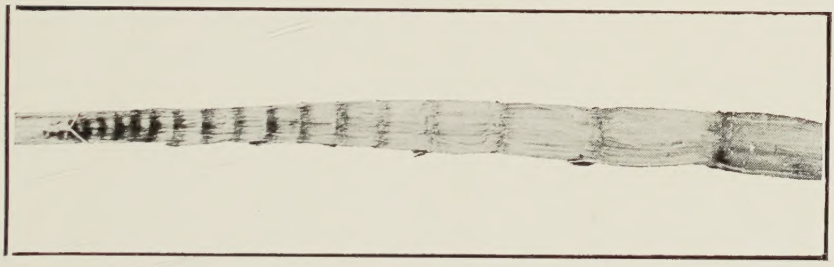

Fig. 37.

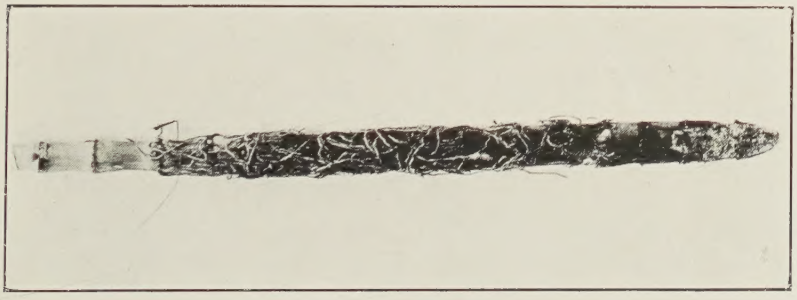

Fig. 38.

A. J. Cumming, Government Printer, Brisbane.